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Diversity and Distribution of Bat Species on Chuck Swan Wildlife Management Area, Tennessee

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To the Graduate Council:

I am submitting herewith a thesis written by Meaghan Shipley Wear entitled "Diversity and Distribution of Bat Species on Chuck Swan Wildlife Management Area, Tennessee." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

Lisa I. Muller, Major Professor

We have read this thesis and recommend its acceptance:

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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We have read this thesis and recommend its acceptance:

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Vice Chancellor and Dean of Graduate Studies

DIVERSITY AND DISTRIBUTION OF BAT SPECIES ON CHUCK SWAN WILDLIFE MANAGEMENT AREA, TENNESSEE

A Thesis Presented for the

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Meaghan Shipley Wear

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ABSTRACT

Bats are an important component of forest ecosystems. The bats present in southern forests use echolocation to consume great numbers of insects each year. Of the 22 bat species in the southeastern United States, 14 are known to occur in Tennessee. The gray bat (*Myotis grisescens*) and the Indiana bat (*Myotis sodalis*), are endangered. However, there has been limited research on bats in Tennessee. This study was designed to identify diversity and distribution of bat species on Chuck Swan Wildlife Management Area (CSWMA), Tennessee.

During summer (late May through mid August) 2002 and 2003, 74 and 85 locations, respectively were randomly chosen at CSWMA and actively sampled for bat activity using the Anabat II system to record echolocation calls of bats. The Anabat system transforms those calls into frequencies audible to humans. The calls can then be analyzed in the program Analook. Echolocation calls of most bats are species specific. Active sampling occurred for 20 minutes at each sampling site. Bat detectors were moved to the direction of the bats as they were heard. At each site, habitat type, slope, aspect, temperature, % cloud cover, wind, % canopy cover, % shrub cover, litter depth, number of snags, number of trees with exfoliating bark, and whether or not water was within 10 m of the site was recorded. During fall, 5 September through 15 November 2003, Anabat II detectors were placed in waterproof containers at 2 of the entrances to 3 caves. Sites were continuously monitored from 8:00 p.m. to 6:00 a.m., except for days when rain was forecasted by the National Weather Service.

Eight different species of bats were identified by echolocation at the active sampling sites. Species included big brown bats (*Eptesicus fuscus*), silver-haired bats (*Lasionycteris noctivagans*), eastern red bats (*Lasiurus borealis*), hoary bats (*Lasiurus cinereus*), little brown bats (*Myotis lucifugus*), Indiana bats, evening bats (*Nycticeius humeralis*), and eastern pipistrelles (*Pipistrellus subflavus*). Fisher's exact tests and Multivariate Analysis of Variance were used to determine species habitat relationships. Hoary bats occurred in different habitat types ($P<0.001$) and canopy cover ($P<0.001$) than all other species. Little brown bats differed from eastern red bats ($P=0.038$). Hoary bats occurred in less shrub cover than big brown bats, eastern red bats, silver-haired bats, evening bats, and eastern pipistrelles.

Seven species of bats were identified at the cave sites, including big brown bats, eastern red bats, hoary bats, little brown bats, Indiana bats, evening bats, and eastern pipistrelles. As temperatures fell during the fall, bat activity greatly decreased at cave sites.

Individual bat species use many different habitat types. A variety of areas are required for day and night roosts, foraging areas, and summer and winter roosts. It is important for CSWMA to remain diverse in habitat type and structure in order to provide suitable habitat for many bats species.

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PART 1: JUSTIFICATION AND LITERATURE REVIEW

RESEARCH NEEDS/ OBJECTIVES

Bats are an important component of forest ecosystems. The 22 species of bats that are present in southern forests are insectivorous and use echolocation to consume great numbers of insects each year (Harvey and Saugey 2001). Of the 22 species, 14, consisting of 7 genera, are known to occur in Tennessee (Table 1; all tables and figures located in appendix). Two of these, the gray bat (*Myotis grisescens*) and the Indiana bat (*Myotis sodalis*), are endangered (Harvey and Britzke 2002). Studies have shown that populations of many bat species have been declining over the past few decades (Humphrey 1978, Tuttle 1979, Hill and Smith 1984, Pierson 1998). The largest factor contributing to population declines is the destruction of roost sites, particularly hibernacula (Humphrey 1978, Sheffield et al. 1992). Most past conservation efforts have focused on protection of hibernacula (Trombulak et al. 2001). Other factors contributing to population declines include: pesticide poisoning (Geluso et al. 1976, Reidinger 1976, Tuttle 1979), chemical pollution (Tuttle 1979), siltation of waterways (Tuttle 1979), flooding (Hall 1962), deforestation (Tuttle 1979), and human interference (Humphrey 1978, Speakman et al. 1991, Sheffield et al. 1992). However, despite population declines, there has been limited research on many bat species in Tennessee (Harvey and Britzke 2002). Objectives of this study were to determine which bat species utilize Chuck Swan Wildlife Management Area (CSWMA), Tennessee (Figure 1), and to examine use of caves on the management area.

BAT SAMPLING TECHNIQUES

Due to their small size and nocturnal behavior, bats are relatively difficult to study. There are many different techniques for sampling bats, including capture (e.g., mist nets, hoop nets, harp traps, et.) and non-capture (e.g., roost counts, visual counts and ultrasonic detectors) methods.

Mist nets are used to capture bats while they are feeding, and are usually set over water or where bats fly when coming off of the roost. Mists nets can be used to collect demographic data (Murray et al. 1999). However, netting causes stress, and some species are much more likely to be caught than others (Murray et al. 1999). The northern long-eared bat (*Myotis evotis*) forages in low vegetative clutter and is more likely to be caught in a mist net. Silver-haired bats (*Lasionycteris noctivagans*) forage at high altitudes in the open or above tree canopies, and are usually not caught in mist nets (O'Farrell and Gannon 1999).

Hoop nets (also called hand nets) consist of an adjustable length pole with a bag, usually made of mosquito netting (Kunz and Kurta 1988). Hoop nets are most effective in capturing bats which roost in foliage, hollow trees, buttress cavities, caves, and mines (Jones et al. 1996). Hoop nets can also be used to capture flying bats as they exit from small openings (Kunz and Kurta 1988). Bats may become habituated to hoop nets and may avoid subsequent capture (Kunz and Kurta 1988).

A harp trap is a large frame with fine wire, which is not detected visually or acoustically by bats (Constantine 1958). Bats flying in a familiar area will often use spatial memory rather than echolocation to navigate flight and may be trapped easily with harp traps (Jones et al. 1996). Traps are placed in natural flyways (usually near openings in caves, buildings or hollow trees, along trails, along ridges, and over streams and small ponds) to capture bats as they go to and from the roost (Jones et al. 1996). Bats will hit the wires and then fall into a holding bag below the frame. Harp traps require minimal attendance compared to other methods for capturing flying bats; however, potential problems include rabies transfer from one bat to another, suffocation if large numbers are caught in a short time period, and predation on bats while they are trapped in the bag (Kunz and Kurta 1988).

Roosting groups of bats may consist of 1 or more species. Roosts are commonly surveyed or censused, since roosts are relatively easy to locate and usually have moderate to high numbers of individuals. Most roosts are also relatively permanent, and, with enclosed roosts, they may be logistically simple to study (Thomas and LaVal 1988).

There are several ways to conduct visual counts. Visual emergence counts are often used to count bats exiting from a roost at dusk. Visual foraging counts, are preformed by multiple observers along transects of variable length during a 30 minute period after dusk. This is often done in either strip or circular plots (Thomas and LaVal 1988).

Ultrasonic acoustical monitoring equipment has enabled researchers to quickly and efficiently inventory bat communities (O'Farrell and Gannon 1999), and it allows researchers to examine differences in activity of bats among habitat types (Brigham et al. 1997, Zimmerman and Glanz 2000). A variety of bat detectors have been used over the past 30 years to identify bats by echolocation calls. One bat detection system, the Rascal system (Rascal Recorders, Inc., Livonia, Michigan, USA), provides computer analysis of the time-expanded recordings. This system is accurate; however, it is extremely expensive (Fenton et al. 2001). Pettersson detectors (Pettersson Elektronik, Uppsala, Sweden) range in ability using heterodyning, frequency division, and/or time expansion to analyze bat calls. However, these systems are also very expensive (Jones 1993).

The Anabat system (Titley Electronics, Ballina, New South Wales, Australia) enables researchers to record echolocation calls of bats and transform those calls into frequencies which are audible to humans (Parsons et al. 2000) by dividing by a preset division ratio (Murray et al. 2001). This system can be used with two different sampling techniques: active and passive sampling. Active sampling uses a broad band bat detector (20-200 kHz) with a condenser microphone (Anabat II detector), a Zero-Crossing Analysis Interface Module (ZCAIM), and a laptop computer. Once a bat flies within range, the detector records the echolocation call and processes the call by a zero-crossing period meter (Fenton et al. 2001). The call is then transferred from the ZCAIM to the laptop computer, where the call is saved for future analysis. Active sampling moves the anabat detector towards the calls as they are heard. Active sampling maximizes quality and quantity of diagnostic calls and provides a contextual base for the researcher (O'Farrell et al. 1999). Passive sampling is similar in that it uses an Anabat II detector and a ZCAIM. However, the ZCAIM has been modified with a memory card for directly saving the calls, allowing the Anabat detector to be left in the field.

Anabat II detectors are less expensive and may be used to passively monitor sites. However, some species can be difficult to distinguish from one another, such as an eastern red bat (*Lasiurus borealis*) versus an evening bat (*Nycticeius humeralis*), and some species are more detectable than others (Jones 1993). Some bats show individual and geographical variation in calls, which can further make identification challenging. One disadvantage to the anabat system is it's inability to detect low intensity echolocation calls, for example calls from the northern long-eared bat (*Myotis septentrionalis*) are at a lower intensity than most other bats and are often missed with acoustical monitoring (Faure et al. 1993, Murray et al. 1999). However, anabats are capable of sampling bats that routinely fly outside the sampling capabilities of nets and traps (O'Farrell and Gannon 1999), and they will consistently detect more species in a given area than non echolocation methods (Murray et al. 1999).

HABITAT REQUIREMENTS OF BATS OCCURRING IN TENNESSEE

In managed forest ecosystems of the Appalachians, detailed knowledge about roosting requirements for many common and endangered bat species is insufficient to provide and manage roost habitat (Menzel et al. 2002). However, concern with the status of forest-dwelling bats has resulted in more effort to determine specific habitat requirements (Brigham and Barclay 1996, Fenton 1997).

Cave requirements for bats must also be determined. Caves are important for part or all of the year for many bat species occurring in Tennessee. Caves are especially important for both of the endangered species, as well as the 3 bats listed as special concern including Rafinesque's big-eared bat (*Corynorhinus rafinesquii*), southeastern bat (*Myotis austroriparius*), and eastern small-footed bat (*Myotis leibii*; Harvey and Britzke 2002). Sixty-eight caves in Tennessee are listed as Priority 1, 2, or 3 caves (priority of caves is species specific) for Indiana and/or gray bats as determined by the Gray bat and Indiana bat recovery plans (Harvey and Britzke 2002).

Rafinesque's Big-Eared Bat (*Corynorhinus rafinesquii*)

Historically, Rafinesque's big-eared bats were found within the range of great cypress (*Taxodium spp.*) swamps. As those swamps have been lost, their range has become limited (Harvey and Saugey 2001). They have been located in a relatively small number of sites throughout Tennessee (Harvey and Britzke 2002). During summer they often roost in buildings or hollow trees. During winter months, they can be found hibernating in caves, mines, or similar habitats such as cisterns or wells (Harvey and Britzke 2002, Harvey and Saugey 2001). Many caves in east Tennessee have small numbers (usually 1-5 individuals) of Rafinesque's big-eared bats during winter hibernation (Harvey and Britzke 2002). Unlike many bats, Rafinesque's big-eared bats emerge late in the evening to forage rather than at twilight. This species has declined in past decades due to the loss of summer roosting and foraging habitat and disturbance to winter hibernacula (Harvey and Saugey 2001).

Big Brown Bat (*Eptesicus fuscus*)

The big brown bat can be found in virtually every habitat. In the past big brown bats have been known to form maternity colonies under loose bark or in cavities of trees including species such as pine (*Pinus spp.*), oak (*Quercus spp.*), beech (*Fagus spp.*), and bald cypress (*Taxodium distichum*). Today, many summer roost can also be found in attics, barns, bridges, and other man-made structures, such as bat houses (Harvey and Saugey 2001). They emerge at dusk flying 6-10 m above ground (Harvey et al. 1999).

During winter, big brown bats usually move into caves, mines, or other underground structures, though they usually only hibernate during the coldest weather (Harvey and Saugey 2001) and frequently remain active into November and December (Tuttle 1988). They are usually found hanging singly near cave entrances during winter (Harvey and Britzke 2002).

Silver-Haired Bat (*Lasionycteris noctivagans*)

Silver-haired bats are a temporary species in Tennessee (Harvey and Britzke 2002); however, they are one of the area's most abundant species during April migration (Tuttle 1988). They can also be found in the eastern part of the state during May and June, and then again during migration in early fall (Harvey and Britzke 2002). They are very common in forested areas, primarily coniferous, mixed-coniferous, and deciduous habitats, and especially those with old growth areas (Harvey and Saugey 2001). In Tennessee they have been found hibernating in deep cliff-face crevices (Tuttle 1988). Maternity colonies are formed in tree cavities and small hollows. Though silver-haired bats are dependent on old growth areas for roosting, they also depend on disturbed areas for foraging (Harvey and Saugey 2001). They forage at heights up to 7 m (Harvey et al. 1999). Therefore, it is important to manage forests for diverse age structure and to maintain forest corridors. Silver-haired bats typically hibernate in forested areas (e.g. small tree hollows, under exfoliating bark, in wood piles, in cliff faces), though occasionally they will hibernate in caves entrances (Harvey and Saugey 2001).

Eastern Red Bat (*Lasiurus borealis*)

During the summer, the eastern red bat is the most commonly captured bat in Tennessee (Harvey and Britzke 2002). Eastern red bats are often found roosting in the foliage of deciduous trees, usually hanging by one foot giving the appearance of dead leaves. They are seldom found far from forests (Tuttle 1988). Though these bats rarely enter caves, they often swarm around cave entrances during the fall (Harvey and Saugey 2001). They are often seen flying on warm winter days (Harvey and Britzke 2002).

Hoary Bat (*Lasiurus cinereus*)

Hoary bats are one of the largest North American bat species. They are the most wide-spread bat in the United States (Harvey at al. 1991), but they are rarely seen by humans because they are not attracted to man-made structures. They usually roost along forest edges in trees about 3-5 m above ground. Hoary bats are usually solitary, except during migration. (Harvey and Saugey 2001). Most hoary bats observed in Tennessee are just migrating to other areas; however some individuals will reside in Tennessee during the summer (Harvey and Britzke 2002).

Seminole Bat (*Lasiurus seminolus*)

Seminole bat distribution is primarily south of Tennessee along the coastal plain; however, several Seminole bats have been captured in the state in recent years (Harvey and Britzke 2002). Seminole bats are found roosting in caves, beneath loose bark, in foliage, and in Spanish moss (*Tillandsia usneoides*). They often select roosts sites in moss on the southwestern exposure of trees. They will fly on warm nights during the middle of winter (Harvey and Saugey 2001).

Southeastern Bat (*Myotis austroriparius*)

Southeastern bats can be found throughout the southeast, however few maternity colonies have been found outside of Florida (Harvey and Saugey 2001). In Tennessee, they are primarily found in the western part of the state in the bottomland hardwood forests (Harvey and Britzke 2002). Caves are the typical choice for roosting sites; however, buildings and other structures are occasionally used as well. Throughout the southern part of their range, southeastern bats can be found in buildings and hollow caves. This species is usually associated with bodies of water, since they forage low, close to the water's edge (Harvey and Saugey 2001).

Gray Bat (*Myotis grisescens*)

Gray bats are a year-round cave dwelling species (Johnson 2002). They usually occupy different caves during summer and winter months (Harvey and Saugey 2001). Few gray bats have been found roosting outside of caves. Tuttle (1979) found that 95 % of gray bats aggregated in only 9 caves during winter months. Populations were rapidly decreasing due to human disturbance of hibernacula and maternity caves (Tuttle 1979). More recent studies have shown stable to increasing populations at both winter and summer caves (Harvey and Britzke 2002). However, 95% of gray bats were still known to aggregate in only 10 caves during winter months in 2002 (Harvey and Saugey 2001).

Gray bats use many caves throughout central and eastern Tennessee, including Oaks Cave, located on CSWMA (Figure 2; Harvey and Britzke 2002). Oaks cave is used during summer months by gray bats. Oaks cave is a priority 1 cave for gray bats, and listed as a primary maternity cave. Gray bat priority 1 caves are major hibernacula and important maternity colonies. Gray bat priority 2 caves have fewer bats, but are still important for geographic or other reasons. Gray bat priority 3 caves are caves which still require further research (Harvey and Britzke 2002). A gray bat primary maternity cave in east Tennessee is defined as a cave that has been occupied in the past, or is currently occupied by 10,000 or more gray bats (Harvey and Britzke 2002).

Eastern Small-Footed Bat (*Myotis leibii*)

Eastern small-footed bats hibernate in caves and mines, and are considered one of the hardiest of cave bats. They are one of the last bats to enter caves, and are often found near the entrance, where temperatures can drop below freezing and humidity is low (Harvey and Saugey 2001). In the north, they are common in areas with exposed rock. Recent colonies have been found in east Tennessee in bridges (Harvey and Britzke 2002). During summer they roost in caves and buildings. The forage just after sunset, flying 1-3 m above ground (Harvey and Saugey 2001).

Little Brown Bat (*Myotis lucifugus*)

Little brown bats hibernate in caves and mines during the winter (Harvey and Saugey 2001). Little brown bats are commonly found inhabiting the same caves as Indiana bats (Harvey and Britzke 2002). During summer months, they can be found in a variety of habitat types. They often forage over water, but they can also be found foraging among trees in open areas (Harvey and Saugey 2001).

Northern Long-Eared Bat (*Myotis septentrionalis*)

Northern long-eared bats hibernate in parts of caves and mines that are cool, moist, and where the air is still (Harvey and Saugey 2001); however, few have been observed in Tennessee caves (Harvey and Britzke 2002). During the summer, they use a variety of habitat for day roosts, however, they primarily use caves to roost at night. Northern long-eared bats forage on forested hillsides and ridges rather than streams and floodplain forests (Harvey et al. 1999, Harvey and Saugey 2001, Owen et al. 2003). The northern long-eared bat is known to have a low intensity echolocation call (Faure et al. 1993, Murray et al. 1999), and is often not detected by acoustical monitoring though it may be the most commonly encountered species in a concurrent mist net survey (Owen et al. 2001, Menzel et al. 2002).

Indiana Bat (*Myotis sodalis*)

During summer months, Indiana bats are often found roosting under exfoliating bark of dead trees, or in cavities (Harvey et al. 1991, Harvey and Saugey 2001), generally in wooded streamside habitat (Harvey et al. 1991, Harvey and Britzke 2002). Indiana bats primarily use caves during winter months. During the winter, 85 % of Indiana bats can be found in 9 priority 1 caves in Indiana, Kentucky, and Missouri. The other 15 % can be found in over 50 priority 2 and 3 caves in many eastern states, including Tennessee (Humphrey 1978; U.S. Department of the Interior Fish and Wildlife Service 1996). Indiana bat priority 1 caves contain at least 30,000 bats (U.S. Department of the Interior Fish and Wildlife Service 1996). Priority 2 caves contain 500-30,000 bats, and priority 3 caves contain less than 500 bats (U.S. Department of the Interior Fish and Wildlife Service 1996). Tennessee has no priority 1 caves for Indiana bats. Though Indiana bats are not specifically known to occur in any caves located on CSWMA, there have been recent records of Indiana bats using caves within other parts of Campbell County, Tennessee (Harvey and Britzke 2002).

Evening Bat (*Nycticeius humeralis*)

The evening bat is considered to be a true forest bat and is almost never found in caves; however, they have been known to join bats swarming in front of cave entrances during late summer and early fall. Nursery colonies are formed in hollow trees, underneath loose bark, and in buildings and attics. They have been known to share roosts with Brazilian free-tailed bats. Not much is known about their winter habitat, but they develop large fat reserves during fall, sufficient enough for a long hibernation or migration (Harvey and Saugey 2001).

Eastern Pipistrelle (*Pipistrellus subflavus*)

The eastern pipistrelle is one of the most common bats throughout eastern forests (Harvey and Saugey 2001), and the most commonly encountered cave bat in Tennessee (Harvey and Britzke 2002). Since they are able to tolerate a wide range of temperature, humidity and disturbance, a large number (approximately 8,000) of suitable caves can be found in Tennessee (Harvey and Britzke 2002). Winter habitat consists of caves, mines, and rock crevices. They rarely occupy buildings. This species occupies more caves in eastern North America than any other bat species, usually occupying the warmer parts of the cave. An individual may use the exact same spot in a particular cave or mine on consecutive winters (Harvey and Saugey 2001).

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PART 2: DIVERSITY AND DISTRIBUTION OF BAT SPECIES ON CHUCK SWAN WILDLIFE MANAGEMENT AREA, TENNESSEE

INTRODUCTION

Many studies have shown population declines for several species of bats in recent decades (Pierson 1998, Hill and Smith 1984, Tuttle 1979, Humphrey 1978). However, bat conservation and management has been difficult due to a lack of general information on specific habitat requirements and population trends (Kunz 1988, Fenton 1997). Currently there are 4 species and 3 subspecies of bats listed as endangered by the U.S. Fish and Wildlife Service. Two of these, the gray bat (*Myotis grisescens*) and the Indiana bat (*Myotis sodalis*) occur in Tennessee (Harvey et al. 1999). Surveys of bat species and populations are needed to understand diversity and distribution in order for effective conservation.

Chuck Swan Wildlife Management Area (CSWMA), Tennessee is an important location for bat species. Multiple management practices occur on the area, providing key habitat requirements for many bat species. However, bat research has primarily focused on cave use by endangered species in the summer. An inventory of bat species could provide important information on key habitat components.

There are many ways to survey bat communities such as with roost counts, visual counts, and ultrasonic detection. Roost counts and visual counts can be time consuming and can require many observers. Ultrasonic acoustical monitoring enables researchers to quickly and efficiently inventory bat communities (O'Farrell and Gannon 1999). Anabat

II bat detectors are one type of ultrasonic acoustical monitoring. These monitors provide a cost and time efficient way for researchers to sample bat communities (Murray et al. 1999, O'Farrell and Gannon 1999). The anabat system uses a broadband (20-200 kHz) bat detector with a condenser microphone (Anabat II detector), a Zero-Crossing Analysis Interface Module (ZCAIM), and a laptop computer (Fenton et al. 2001). Some anabat detectors use a ZCAIM that has been modified with a memory card rather than using a laptop computer, so that equipment can be left in the field to passively sample bats (Fenton et al. 2001). The anabat detector divides the frequency of the incoming echolocation call by a preset division ratio, transforming the signal into a range which is audible to humans (Murray et al. 2001). The call is processed by a zero-crossing period meter (Fenton et al. 2001), and saved to the laptop or memory card for future analysis (Murray et al. 2001).

MATERIALS AND METHODS

Study Area

This study was conducted at Chuck Swan Wildlife Management Area (CSWMA), a 10,000-ha management area, located in Union and Campbell Counties, Tennessee (Figure 1; all tables and figures located in appendix). The management area is located near the town of Sharp's Chapel in East Tennessee. The area was acquired by Tennessee Valley Authority (TVA) in 1934 as part of the land acquisition for the construction of Norris Dam. Chuck Swan Wildlife Management Area is co-managed by the Tennessee Division of Forestry and the Tennessee Wildlife Resource Agency (TWRA; Jackson 2002).

Chuck Swan Wildlife Management Area is actively managed for timber, wildlife, and recreation. Mixed hardwood forest is the dominant habitat type. Predominant species include white oak (*Quercus alba*), chestnut oak (*Quercus montana*), black oak (*Quercus velutina*), scarlet oak (*Quercus coccinea*), blackgum (*Nyssa sylvatica*), red maple (*Acer rubrum*), and yellow poplar (*Liriodendron tulipifera*). Most of the pine forest, which primarily consists of loblolly pine (*Pinus taeda*) and eastern white pine (*Pinus strobus*), has been logged or killed due to the southern pine beetle (*Dendroctonus frontalis*). In addition, there are 240 fields which primarily consist of wheat (*Triticum aestivum*), millet (*Urochloa ramose*) and sunflower (*Helianthus annuus*) and cover approximately 6% of the area (600 ha; Figure 3). The area is connected with gravel and dirt roads and contains several caves, springs, and sink holes (Jackson 2002).

Elevation for CSWMA ranges from 305 m to over 488 m above sea level. The average high and low temperatures are 20.4°C and 7.9°C, respectively. Average annual rainfall for CSWMA is approximately 1194 mm (National Oceanic Atmospheric Administration 2000).

Acoustical Monitoring

Summer sampling. -- Anabat II bat detectors (Titley Electronics, Ballina, New South Wales, Australia), attached to a ZCAIM and a laptop computer, were used to actively monitor summer sample sites. Frequency division ratios were set at 16. The sites were chosen randomly near roads or selected from map points within forest, field, or river edge. During sampling, the anabat detector was turned toward the direction of bats as calls were recorded. Sampling occurred for 20 minutes at each sample site. No sites were resampled during a single sampling year.

Fall sampling. -- Six anabat II detectors, connected to ZCAIMs that were modified with memory cards, were placed in waterproof containers at 2 of the entrances/exits of each of 3 caves. Detectors were placed approximately 1-5 m from each entrance/exit, depending on the most suitable area to hang or place the container. Anabats continuously recorded from 8:00 p.m. until 6:00 a.m., except when removed from the field because rain was forecasted. Weather conditions for the area for each night were recorded from The National Weather Service (National Oceanic Atmospheric Administration 2003).

Bat Call Analysis

Identification of calls was made using the program Analook (Anabat System, Titley Electronics, Ballina, New South Wales, Australia). This program provides computer plots showing changes in frequency over time for the echolocation calls which were recorded by the Anabat system (Fenton et al. 2001). Echolocation calls of most bats are species specific. The duration, range, minimum and maximum frequencies, and slope, which is the rate of change in frequency with time (Fenton et al. 2001) of each call was used to identify species. Though there can be some variation in bat echolocation calls within a species (geographic variation, individual variation, and habitat type call occurred in), we identified calls using a pre-defined key (M.A. Menzel, West Virginia University, unpublished data; Figure 4). For example, a hoary bat (*Lasiurus cinereus*) typically has a minimum call frequency of < 25 kHz (Figure 5), while a little brown bat

(*Myotis lucifugus*) usually has a minimum call frequency of $\geq$ 41 kHz (Figure 6). Also, a little brown bat usually has a slope of $\leq$ 110 (Figure 6), while a northern long-eared bat (*Myotis septentrionalis*), typically has a slope of $\geq$ 200 (Figure 7).

Filters can be set to eliminate noises which might have also been recorded with the bat echolocation calls; however, increasing the filter may eliminate part of the call. A filter setting of 6 was generally used. However, the filter occasionally had to be increased when there was a large amount of background noise from insects or other environmental factors. In contrast, the filter was decreased if the call had little background noise and we were analyzing species with similar call frequencies. For the *Myotis*, once calls were identified to genus, a special filter designed specifically to distinguish *Myotis spp.* from each other was used. Only calls with $\geq$3 individual call pulses were examined for analysis.

Habitat Sampling

Site characteristics were recorded at the time of sampling. Date, global positioning system (GPS) location, temperature, sampling start and stop time, and sampling method (e.g. active versus passive sampling) were recorded. Slope was measured using a clinometer and aspect was measured using a compass. Habitat type was classified as forest, field, or river edge. Forest type was determined by dominant vegetation type. Fields were open areas that were actively managed as fields on the WMA. River edge was any site that was directly on the river, including areas surrounded by forested and open areas. Wind was noted as being none, slight, moderate, or strong. General landform description such as at the top or bottom of a ridge was noted. Percent cloud, shrub, and canopy cover were estimated by sight within 5 m from the sampling point. Number of snags and trees with exfoliating bark, such as that found on a shagbark hickory (*Carya ovata*), were counted within 10 m from the point of sampling. It was noted if there was any water within 10 m of the site.

GIS Analysis

All species records and site characteristics were entered and imported into ArcMap (ESRI, Redlands, California, USA). Landcover data for CSWMA and Union and Campbell county data (rivers, streams, roads, and county boundaries), were downloaded from the Tennessee Spatial Data Server which is provided by the Tennessee Federal GIS Users Group. All data which we obtained from the Tennessee Spatial Data Server was created from the United States census 2000. All maps were then created using ArcMap.

Statistical Analysis

All data were analyzed using SAS (SAS Institute, Cary, North Carolina, USA). Relationships among habitat type, wind, water within 10 m, and species present were analyzed using a Fisher's Exact test. Where no differences occurred among years, data were combined for both years and subsequent analysis by species was performed using combined years. Multivariate analysis of variance (MANOVA) was used to evaluate relationships with all other variables (temperature, % cloud cover, slope, aspect, % canopy cover, % shrub cover, number of snags, litter depth, and number of trees with exfoliating bark) for each species. Pairwise comparisons, using contrast statements, were used to determine where differences occurred.

RESULTS

Acoustical Monitoring

Summer sampling. -- From 28 May through 12 August 2002, 74 locations were actively sampled at CSWMA (Figure 8) using Anabat II bat detectors. During 13 May through 11 August 2003 the same 74 locations, plus 11 additional sites, were actively sampled (Figure 8). During the 2 summers, bat activity was monitored at 159 point count sites (Table 2). Eight different bat species were identified and found in a variety of habitats (Table 3). Species included big brown bats (*Eptesicus fuscus*; Figure 9), silver-haired bats (*Lasionycteris noctivagans*; Figure 10), eastern red bats (*Lasiurus borealis*; Figure 11), hoary bats (Figure 12), little brown bats (Figure 13), Indiana bats (Figure 14), evening bats (*Nycticeius humeralis*; Figure 15), and eastern pipistrelles (*Pipistrellus subflavus*; Figure 16). We also had 51 calls which could only be identified to *Myotis spp*. There were 34 of these in forest and 17 in river edge.

Fall sampling. -- – 5 September through 15 November 2003, 3 caves (Oaks cave, Mossy Springs cave, and Panther cave) were passively sampled (Figure 2). Seven species of bats were found using or swarming around the caves monitored during fall of 2003. Oaks cave had 6 bat species (big brown bats, eastern red bats, hoary bats, little brown bats, evening bats, and eastern pipistrelle; Figure 17). Mossy Springs cave had 4 bat species (big brown bats, eastern red bats, hoary bats, and eastern pipistrelles; Figure 18). Panther cave had 7 bat species (big brown bats, eastern red bats, hoary bats, little brown bats, Indiana bats, evening bats, and eastern pipistrelles; Figure 19).

Overall activity decreased at the caves as temperature decreased (Figures 17-19). However, 5 out of the 7 species found at the caves, were still recorded on the last days of sampling (Table 4). We still recorded calls from big brown bats, evening bats, and eastern pipistrelles when the low temperature dropped to 1.7°C (Table 5).

Habitat Sampling

There was no difference among habitat types between years for sites sampled, so data for the 2 years were combined. There were 30 field sample sites (18.8 %), 97 forest sample sites (61.0 %), and 32 river edge sample sites (20.1 %; Table 2). Species occurrence differed by habitat type sampled ($P<0.001$). No differences among species were found for wind ($P=0.995$) or water within 10 m ($P=0.489$). Canopy cover ($P=0.001$) and shrub cover ($P=0.036$) were statistically different among species. Hoary bats were found in fields (72 % of the time) with mean canopy cover of 16.1%. All other bat species occurred in 60.0-78.5 % canopy cover. Eastern red bats differed from little brown bats ($P=0.038$; 62.1-78.5 % canopy cover, respectively; Table 6). Hoary bats occurred in less mean shrub cover than all the other species recorded (Table 7).

DISCUSSION

Species Accounts

Summer sampling. -- All of the bat species identified during the summer sampling period, except Indiana bats and silver-haired bats, were considered common in Tennessee (Harvey and Saugey 2001). The endangered Indiana bat was found at only 1 location for both years. The silver-haired bat, was found at 1 site during 2002 and 3 sites during 2003. This species is known to migrate through Tennessee, though they are usually gone by the end of June and do not return until early fall (Harvey et al. 1999, Harvey and Britzke 2002). The silver-haired bat was detected at a small number of sites, and, in June, July, and August was likely migrating through the area.

We did not record the northern long-eared bat, which is common throughout Tennessee (Harvey et al. 1999, Harvey and Saugey 2001). Northern long-eared bats forage on forested hillsides and ridges rather than along riparian areas or floodplain ecosystems (Harvey et al. 1999, Harvey and Saugey 2001, Owen et al. 2003). The majority of our sites were forested areas, therefore we should have recorded northern long-eared bats. However, one bias of the use of Anabat acoustical monitoring equipment is the reduced ability to detect low-intensity calls from species such as the northern long-eared bat (Faure et al. 1993, Murray et al. 1999). Northern long-eared bats have often been undetected with Anabat, despite it being the most numerous species encountered in a concurrent mist net survey (Owen et al. 2001, Menzel et al. 2002). Some of our Anabat echolocation calls could only be identified to *Myotis spp.*; therefore, it is likely that some or all of these calls were from northern long-eared bats. The use of Anabat sampling recording directly to a computer or memory card has been improving and overcoming such deficiencies will allow for better resolution of bat activity among habitat types (White and Gehrt 2001, Johnson et al. 2002).

Fall sampling. -- Anabat detectors were placed outside of the caves, pointed at the entrances. Therefore, all species recorded at cave locations may not have been using the caves for roosting. Many species that seldom enter caves, such as evening bats and eastern red bats, will join swarms outside of caves during the fall (Harvey et al. 1999).

Eastern red bats seldom enter caves for any distance. However, it is common to see an eastern red bat flying around on a warm winter day in this area. Eastern red bats will also migrate south from colder parts of their range for the winter. Bat species that migrate, such as the hoary bat and the Indiana bat, will also swarm in passing. Hoary bats have long seasonal migrations during fall and winter months are considered to be passing through Tennessee. Indiana bats usually depart for winter caves during September. They often engage in swarming until mid October, when they enter caves for winter hibernation (Harvey et al. 1999, Harvey and Saugey 2001).

Several species that were recorded at CSWMA caves were likely using the caves for roosting and hibernation, rather than just swarming. Eastern pipistrelles are found in more caves in the eastern United States than any other bat species, and they were the most frequently encountered bat species at CSWMA caves. They inhabit over 8,000 caves in the state of Tennessee (Harvey and Britzke 2002). Big brown bats use caves during the winter, but only during the coldest months. Little brown bats also hibernate in caves; however, they are not as common in Tennessee as they are in the more northern part of their range (Harvey et al. 1999, Harvey and Saugey 2001).

Cave monitoring may have occurred too late in the year for gray bats. Harvey and Britzke (2002) found 5,950 gray bats using Oaks cave during the summer. There were no reports of gray bats using this cave during winter months. Also, there were no reports of gray bats using any of the other caves on CSWMA.

Caves

Temperature data was collected for the area, not for individual caves. Caves could have higher or lower temperatures than the surrounding area. Therefore, we cannot determine specific cave microclimate requirements for bat species found at any of the 3 caves.

Habitat Sampling

Hoary bats are a large species, weighing 25-30 g, and with a wingspan of 34-41 cm (Harvey et al. 1999). They are found in more open areas because of their size. They usually spend days roosting in foliage, but they choose sites which are covered from above and open below (Harvey et al.1999). Our monitoring occurred during the time bats were active. Therefore, we would expect hoary bats to choose the most open areas for the easiest flying. All other species recorded were smaller than the hoary bat. These smaller species were not as affected by shrub and canopy cover.

This study indexed which bat species occurred at CSWMA, however it is possible some species that might be present were not at our sample sites or not detected with our equipment. In order to obtain a thorough and completely accurate index of species, multiple sampling techniques should be used. Using multiple techniques would allow for maximum availability to sample all species which are actually present.

MANAGEMENT IMPLICATIONS

Bats are ecologically important and are affected by forest management (Campbell et al. 1996, Krusic et al. 1996, Morrell et al. 1999). Individual species of bats need and use a variety of different habitat types, including roosting and foraging sites. If bats have specific tree-roost requirements, forest harvesting would cause a direct loss of roost sites, thus having a negative impact (Kalcounis and Hecker 1996, Vonhof and Barclay 1996). On the other hand, harvested sites may have a positive impact on foraging bats by creating openings and edge habitat; however, foraging behavior could be influenced by roost availability and location (Kunz 1982, Brigham 1991).

Currently, a variety of forest management practices are conducted on CSWMA. The area is broken into different managed compartments. Management practices include, logging, shelterwood cuts, clearcuts, burning, and herbicide treatments, et. (D. Bailey, Tennessee Department of Forestry, personal communication). These management practices provide a variety of habitat types at CSWMA. We need to understand how forest harvesting affects bat species to manage for effective conservation (Lehmkuhl and Ruggiero 1991). Future forest management at CSWMA should include collaborative effort from both Tennessee Wildlife Resource Agency (TWRA) and Tennessee Department of Forestry (TDF) in order to maximize habitat availability for bat species.

The Indiana bat was located at the same spot over 2 years, and should continue to be monitored. Mist netting, or other sampling techniques should also be used to confirm species presence. Studies are needed to determine specific habitat requirements for summer roosts, as well as for roosting behavior (Humphrey et al. 1997, Menzel et al. 2001).

In past studies gray bats were found at Oaks cave during summer months (Harvey and Britzke 2002). Passive anabat detectors could easily be placed outside of this cave during summer months to continually monitor activity. This cave should also be monitored for human disturbance, which may affect viability of the population.

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PART 3: CONCLUSIONS

The causes and rates of decline for bats are rarely well documented (Tuttle 1979). Further studies are needed to in order to determine specific habitat requirements, so that declining bat populations can be protected from future endangerment, and endangered populations can be restored.

Ultrasonic detection of bat echolocation calls has become widely used to inventory and study bat communities. Anabat II bat detectors (Titley Electronics, Ballina, New South Wales, Australia), one type of ultrasonic detection system, allows researchers to monitor bat communities in a time and cost efficient way (O'Farrell and Gannon 1999). Acoustical sampling causes minimal disturbance to bat communities (Jones 1993) and is capable of sampling bats which consistently fly outside of the sampling capabilities of nets and traps (O'Farrell and Gannon 1999). However, acoustical monitoring equipment does have limitations. To obtain the most complete and accurate inventory, acoustical monitoring should be used along with various capture techniques (O'Farrell and Gannon 1999).

Today, many state and federal agencies, as well as many private organizations, are actively involved in bat conservation. Some of these organizations include many state wildlife agencies, such as Tennessee Wildlife Resource Agency (TWRA), U.S. Fish and Wildlife Service, U.S. Forest Service, Bureau of Land Management, U.S. Army Corps of Engineers, Tennessee Valley Authority, Biological Resources Division of the U.S. Geological Survey, state parks, natural heritage commissions, Nature Conservatory, National Speleogical Society, Cave Research Foundation, American Cave Conservation Association, and Bat Conservation International (Harvey et al. 1999). The effort from these agencies, as well as the effort from private land owners and wildlife enthusiasts will be vital to the future of bats species (Tuttle 1979).

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O'Farrell, M. J., and W. L. Gannon. 1999. A comparison of acoustic versus capture techniques for the inventory of bats. Journal of Mammalogy 80:24-30.

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APPENDIX

TABLES

Table 1. Species and status of bats that occur in Tennessee.[a]

Scientific name	Common name	Status
Corynorhinus rafinesquii	Rafinesque's big-eared bat	special concern
Eptesicus fuscus	big brown bat	common
Lasionycteris noctivagans	silver-haired bat	uncommon
Lasiurus borealis	eastern red bat	common
Lasiurus cinereus	hoary bat	common
Lasiurus seminolus	Seminole bat	common
Myotis austroriparius	southeastern bat	special concern
Myotis grisescens	gray bat	endangered
Myotis leibii	eastern small-footed bat	special concern
Myotis lucifugus	little brown bat	locally common
Myotis septentrionalis	northern long-eared bat	common
Myotis sodalis	Indiana bat	endangered
Nycticeius humeralis	evening bat	common
Pipistrellus subflavus	eastern pipistrelle	common

[a] data taken from Harvey and Britzke 2002, Harvey and Saugey 2001

Table 2. Total number of sites sampled by year and habitat type during bat echolocation monitoring May-August 2002 and 2003.

	Habitat type			
Year	Field sites	Forest sites	River edge sites	Total sites
2002	15 (20.1 %)	43 (58.1 %)	16 (21.6 %)	74
2003	15 (17.6 %)	54 (63.5 %)	16 (18.8 %)	85
Combined years	30 (18.9 %)	97 (61.0 %)	32 (20.1 %)	159

Table 3. Number of bat species recorded by habitat type using echolocation calls on Chuck Swan Wildlife Management Area, Tennessee, 2002-2003.

	Habitat Type			
	Field[a] n=30	Forest[b] n=97	River edge[c] n=32	Total n=159
Species	Count[d]	Count	Count	Count
Eptesicus fuscus	0	10	8	18
Lasionycteris noctivagans	0	2	2	4
Lasiurus borealis	13	68	28	109
Lasiurus cinereus	13	0	5	18
Myotis lucifugus	0	11	6	17
Myotis sodalis	0	0	2	2
Myotis spp.	0	34	17	54
Nycticeius humeralis	5	43	14	62
Pipistrellus subflavus	1	23	13	37

Table 3 cont.

[a] Fields included all cropland and pasture/grassland.

[b] All forest sites sampled were oak-hickory forest.

[c] Included sites along the edge of the river surrounded by forest and open areas.

[d] The number of sites where each species was recorded.

Table 4. Latest dates bat species were recorded using Anabat II bat detectors at caves on Chuck Swan Wildlife Management Area, Tennessee, 5 September - 15 November 2003.

	Oaks cave	Panther cave	Mossy Springs cave
Species	Latest date[a]	Latest date[a]	Latest date[a]
Eptesicus fuscus	09/13/2003	11/13/2003	10/30/2003
Lasiurus borealis	11/12/2003	11/11/2003	11/10/2003
Lasiurus cinereus	10/21/2003	09/24/2003	NA[b]
Myotis lucifugus	10/21/2003	11/12/2003	09/26/2003
Myotis sodalis	NA[b]	09/06/2003	NA[b]
Nycticeius humeralis	11/12/2003	11/13/2003	NA[b]
Pipistrellus subflavus	11/02/2003	11/15/2003	11/13/2003

[a] The latest date each species was found during the sampling period prior to anabat detectors taken out of the field on 16 November 2003

[b] There was no record of this species at this location

Table 5. Lowest area temperatures (°C) surrounding caves on Chuck Swan Wildlife Management Area, Tennessee, 5 September-15 November 2003; bat species were recorded using Anabat II bat detectors.

	Oaks cave	**Panther cave**	**Mossy Springs cave**
Species	Low temperature[a]	Low temperature[a]	Low temperature[a]
Eptesicus fuscus	15.6	1.7	4.4
Lasiurus borealis	4.4	5.0	4.4
Lasiurus cinereus	12.8	10.6	NA[b]
Myotis lucifugus	12.8	10.0	13.9
Myotis sodalis	NA[b]	16.1	NA[b]
Nycticeius humeralis	10.0	1.7	NA[b]
Pipistrellus subflavus	3.3	3.3	1.7

[a] The lowest temperature (°C) recorded during the sampling period for each species still active

[b] There was no record of this species at this location

Table 6. Mean canopy cover for bat species using pairwise comparisons. Bats were monitored using Anabat II bat detectors May-August 2002 and 2003.

Species	Mean Canopy Cover %	Significance[a]
Eptesicus fuscus	60.00	ABD
Lasiurus borealis	62.06	B
Lasiurus cinereus	16.11	C
Lasionycteris noctivagans	60.00	ABD
Myotis lucifugus	78.53	AD
Myotis sodalis	62.50	ABD
Nycticeius humeralis	63.68	ABD
Pipistrellus subflavus	67.49	ABD

[a] Species with the same letter were not statistically different, as determined from pairwise comparisons.

Table 7. Mean shrub cover for bat species using pairwise comparisons. Bats were monitored using Anabat II bat detectors May-August 2002 and 2003.

Species	Mean Shrub Cover %	Significance[a]
Eptesicus fuscus	23.89	A
Lasiurus borealis	21.70	A
Lasiurus cinereus	11.39	B
Lasionycteris noctivagans	31.26	A
Myotis lucifugus	20.00	A
Myotis sodalis	32.50	A
Nycticeius humeralis	26.53	A
Pipistrellus subflavus	24.87	A

[a] Species with the same letter are not statistically different, as determined from pairwise comparisons.

FIGURES

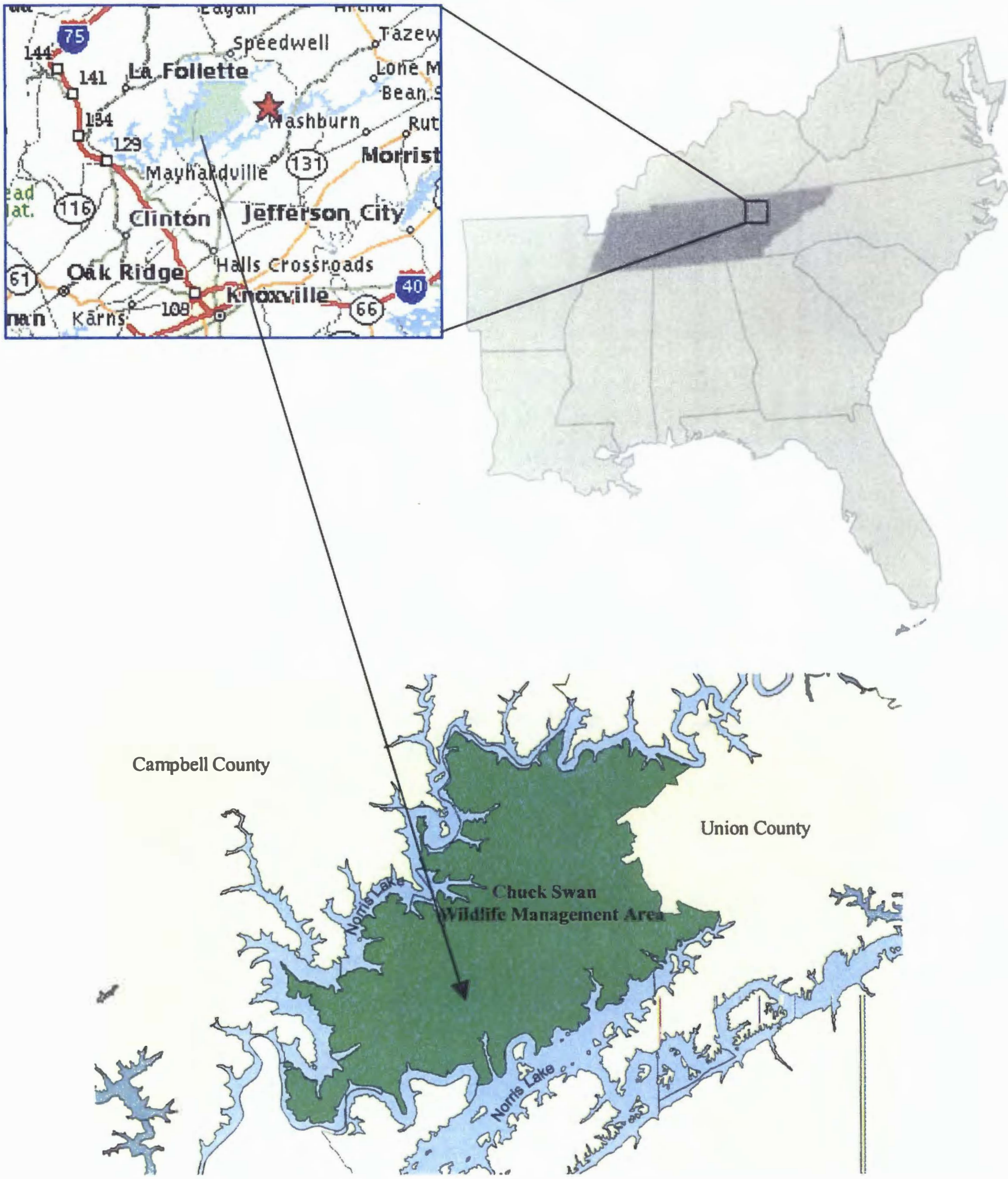


Figure 1. Location of Chuck Swan Wildlife Management Area, Tennessee. This 10,000-ha management area is located in Union and Campbell counties.

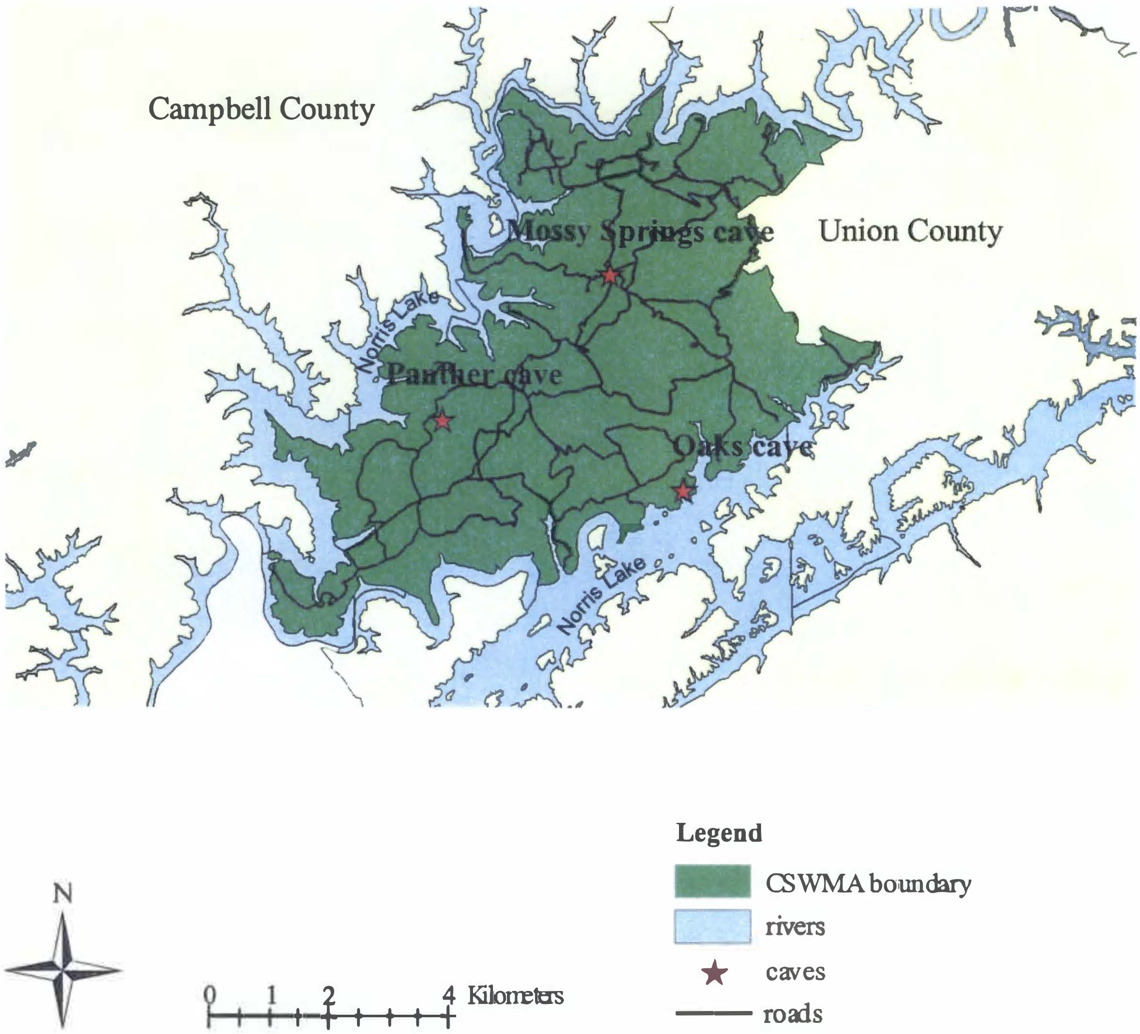


Figure 2. Location of caves sampled with passive Anabat II detectors at Chuck Swan Wildlife Management Area, Tennessee, 5 September-15 November 2003.

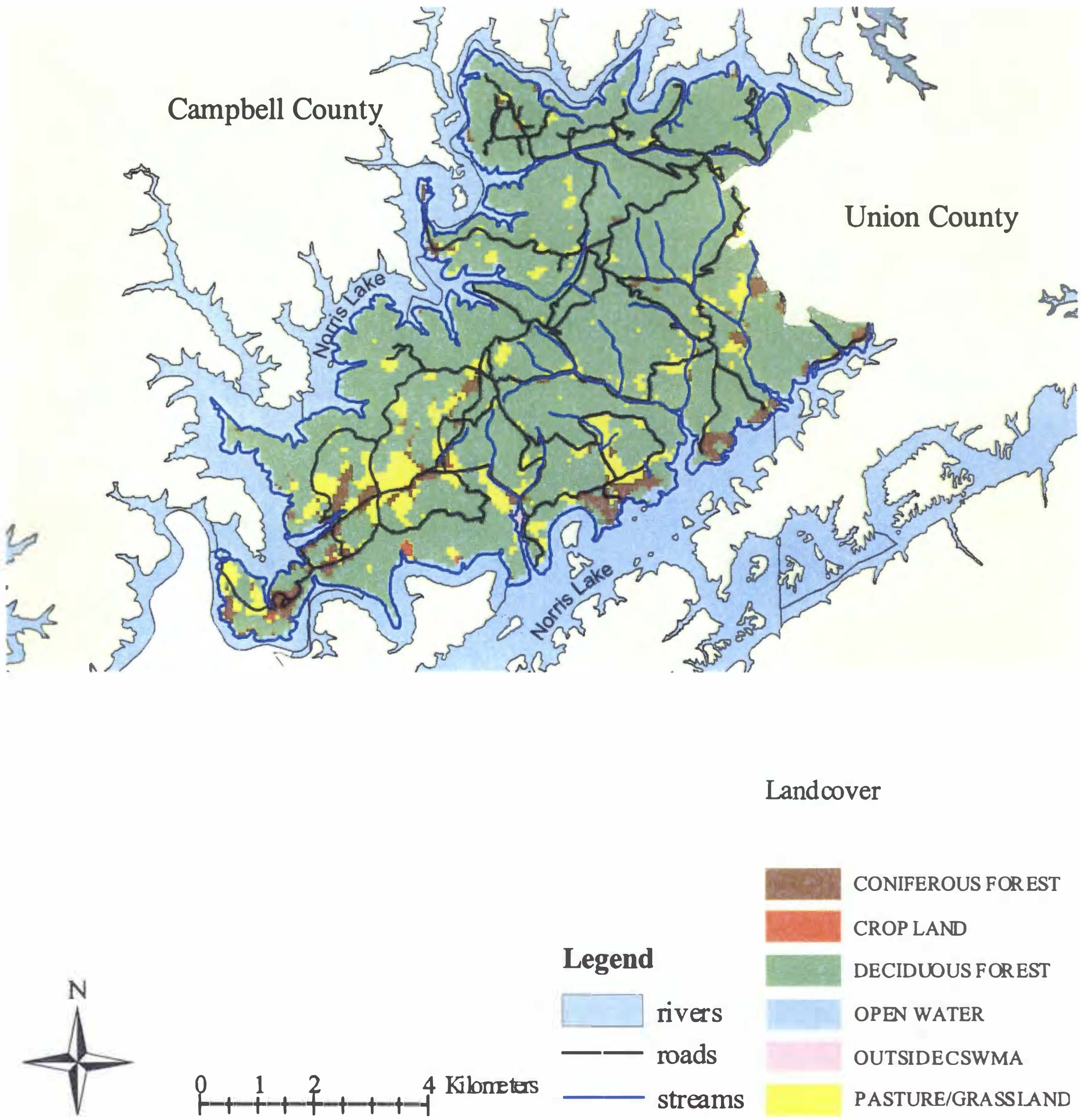


Figure 3. Landcover data of Chuck Swan Wildlife Management Area, Tennessee. Data were obtained from the Tennessee Spatial Data Server, United States Census 2000.

Key to the calls of the bats of West Virginia[a]

1. Call sequence contains $\geq$ 3 pulses of high quality..2

   Call sequence contains $\leq$ 3 pulses of high quality..NOID

2. Minimum call frequency typically < 25 kHz...LACI

   Minimum call frequency typically $\geq$ 25 kHz..3

3. Minimum call frequency typically $\leq$ 31 kHz..4

   Minimum call frequency typically > 31 kHz..5

4. Curvature value of call typically $\geq$ 3, Minimum call frequency usually 26-27 kHz...LANO

   Curvature value of call typically < 3, Minimum call frequency usually 25-26 kHz...EPFU

5. Minimum call frequency 31-40 kHz **and** average call frequency < 43 kHz.........NYHU

   Minimum call frequency $\geq$ 40 kHz **or** average call frequency $\geq$ kHz..........................6

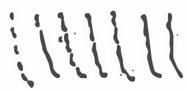
6. Call shaped like  with an average frequency typically 49-53 kHz, a minimum frequency commonly 30-40 kHz, and curvature values typically $\leq$ 2. Curvature values $\geq$ 3 are rare..7

Figure 4. Key to the calls of the bats of West Virginia (M.A. Menzel, West Virginia University, unpublished data; modified by W.M. Ford, U.S. Forest Service, personal communication)

Call shaped like  with an average frequency typically around 45 kHz, a minimum frequency typically ≥ 41 kHz, and curvature values typically > 2. Curvature values of 3 are common. LABO has an even call bottom, while PISU has an uneven call bottom....................LABO/PISU

7. Slope ≥ 200...MYSE

   Slope < 200...8

8. Slope ≤ 110...MYLU

   Slope > 110 and < 200..MYSO

[a]<u>Key to abbreviations</u>

NOID not able to identify
LACI Lasiurus cinereus
LANO Lasionycteris noctivagans
EPFU Eptesicus fuscus
NYHU Nycticeius humeralis
LABO Lasiurus borealis
PISU Pipistrellus subflavus
MYSE Myotis septentrionalis
MYLU Myotis lucifugus
MYSO Myotis sodalis

Figure 4 cont.

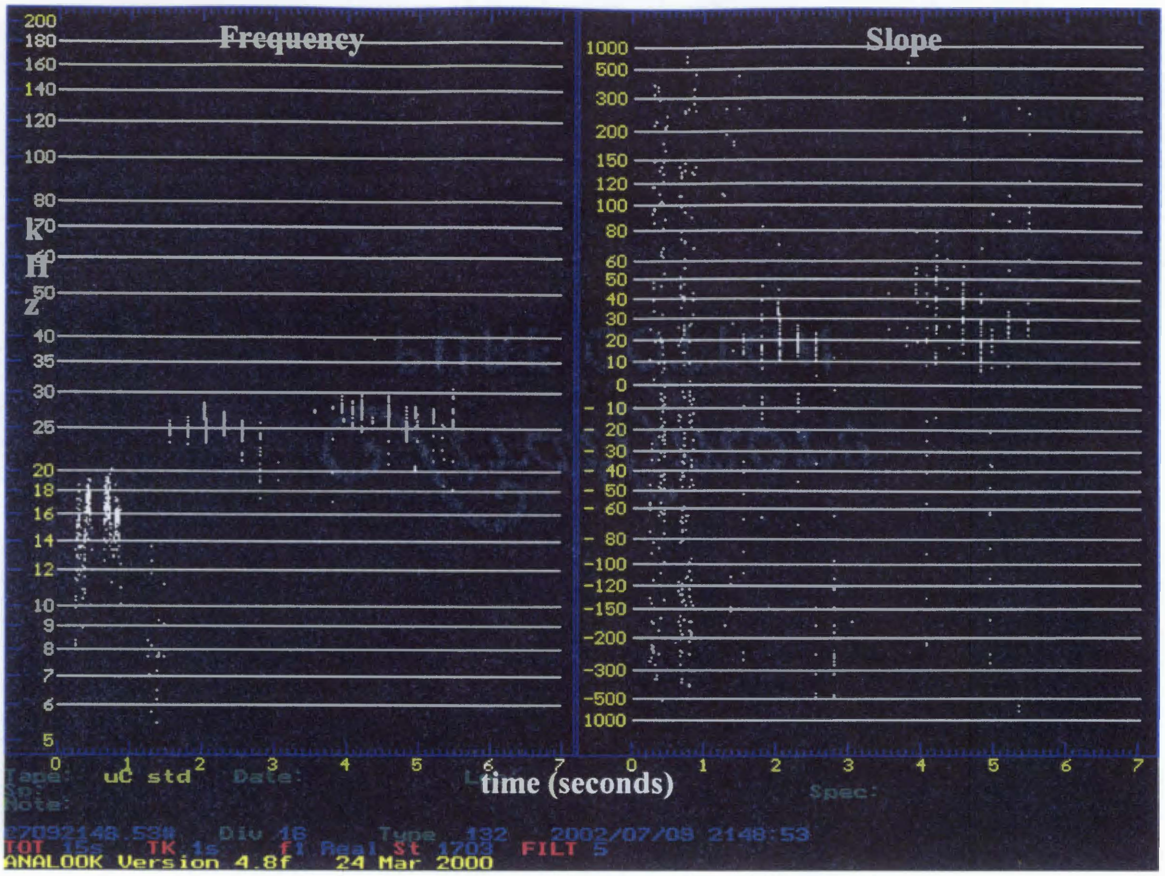


Figure 5. Example of a Hoary bat (*Lasiurus cinereus*) echolocation call in the program Analook.

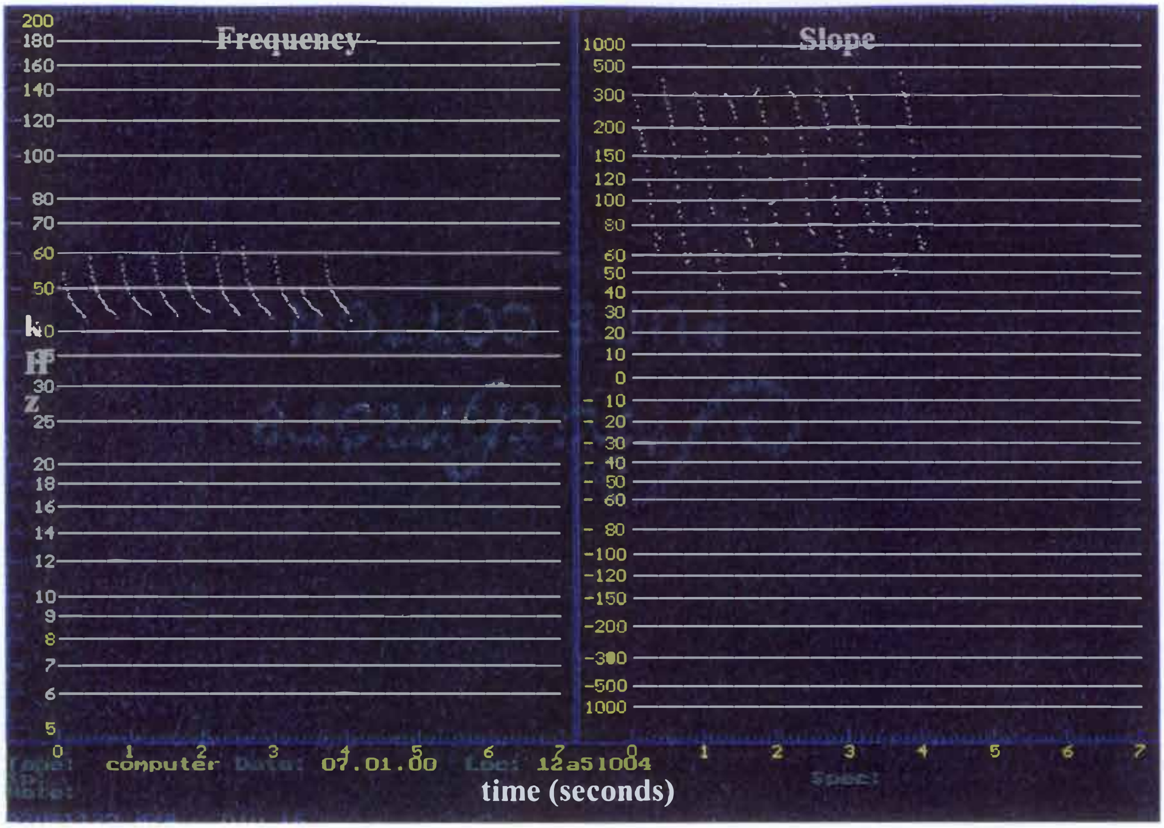


Figure 6. Example of a little brown bat (*Myotis lucifugus*) echolocation call in the program Analook.

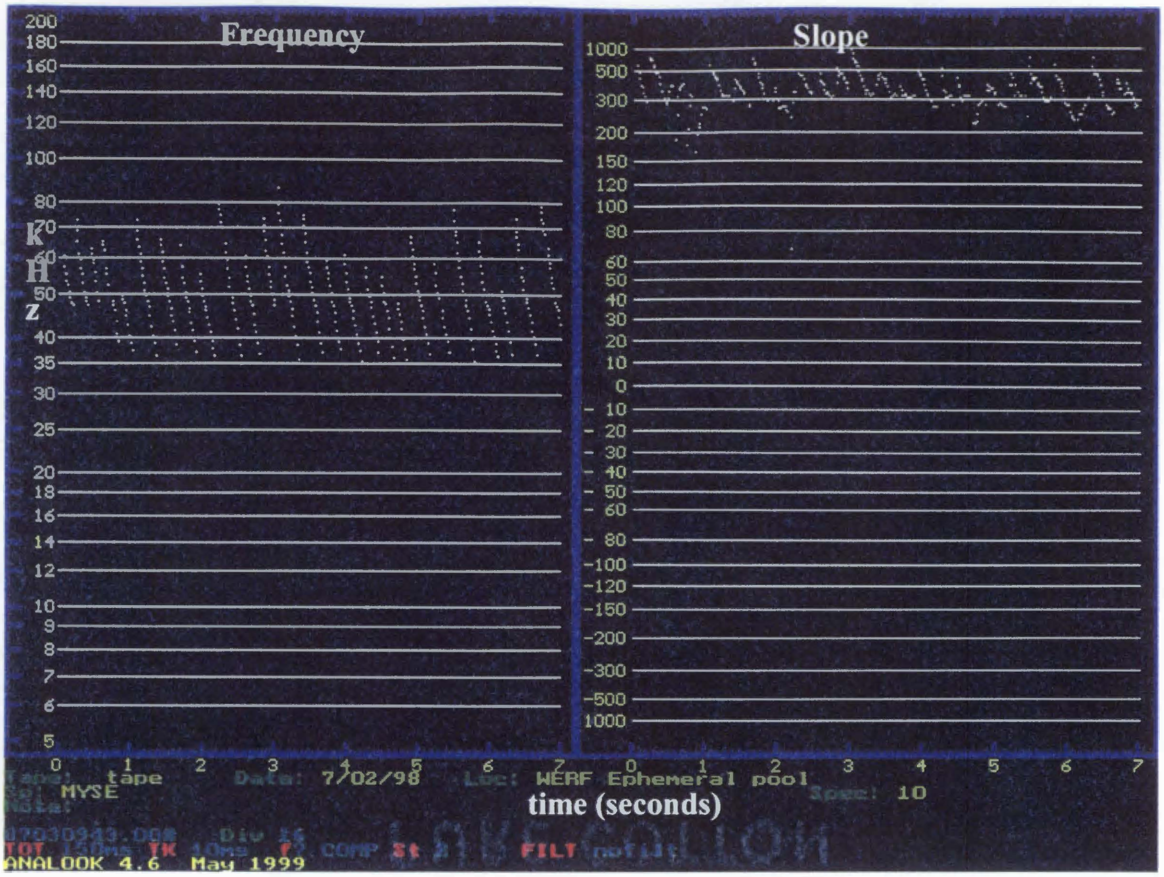


Figure 7. Example of a Northern long-eared bat (*Myotis septentrionalis*) echolocation call in the program Analook.

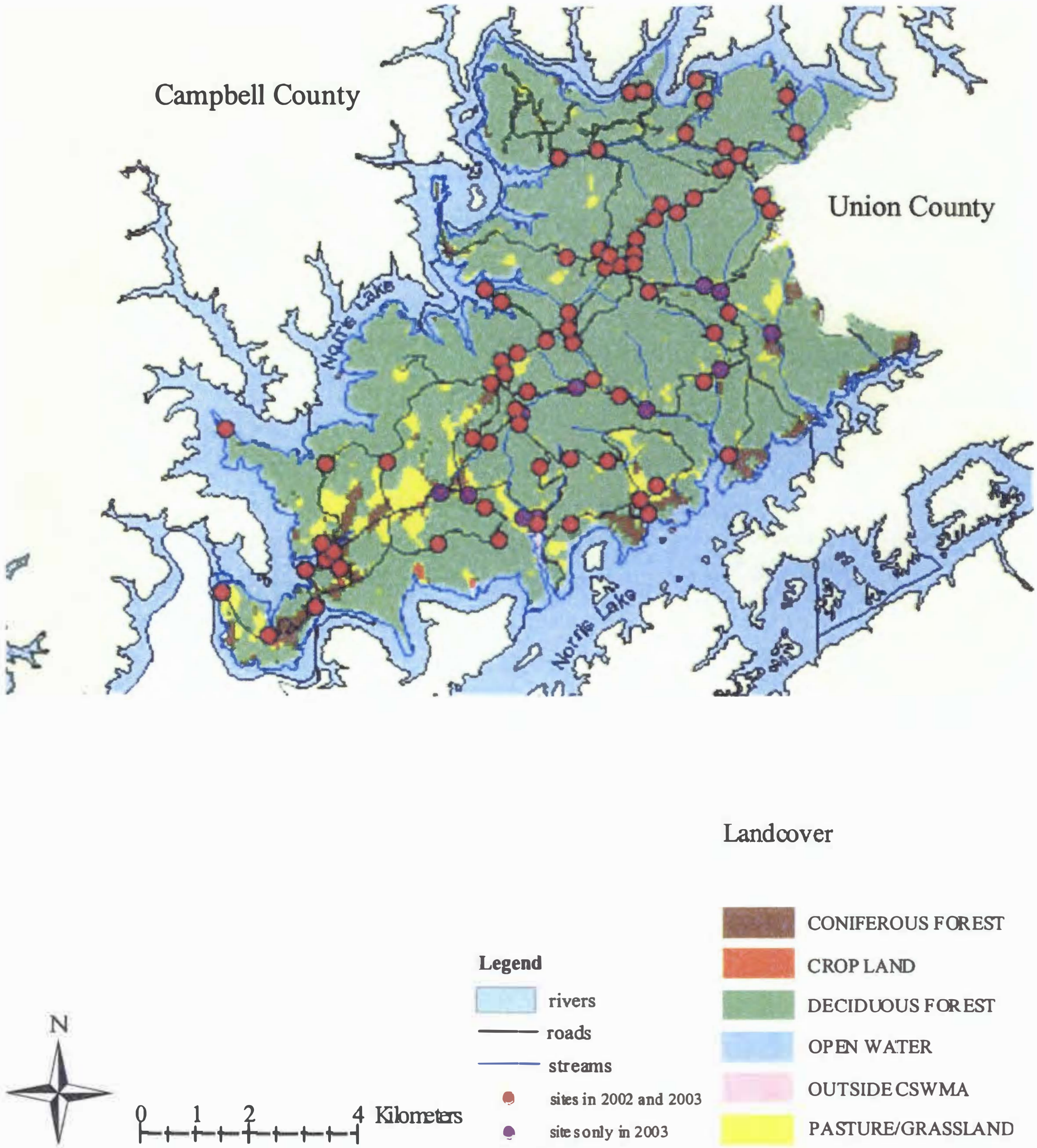


Figure 8. Sample sites for active anabat detector recording of bat species at Chuck Swan Wildlife Management Area, Tennessee, May-August 2002 and 2003.

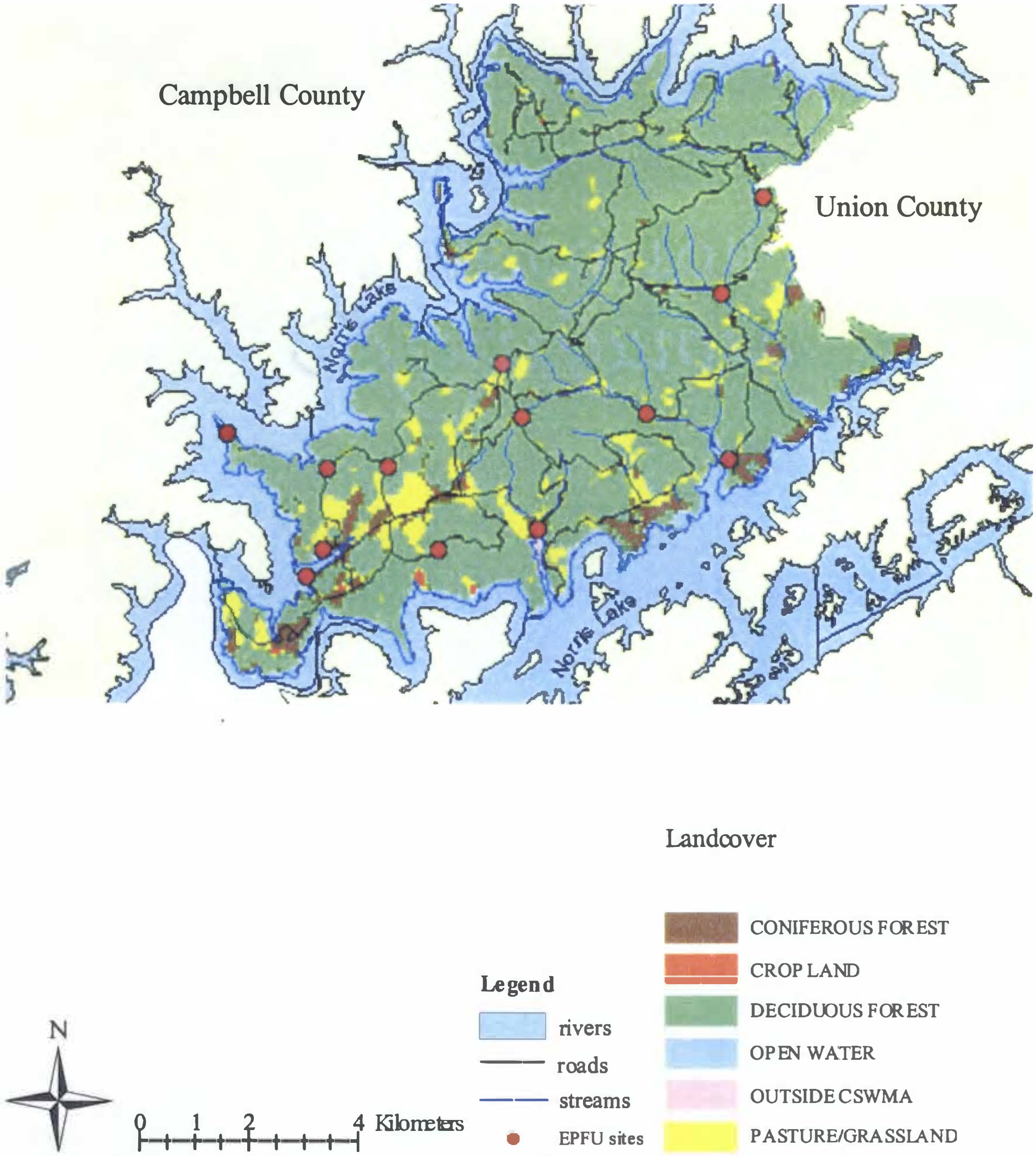


Figure 9. Location of big brown bat (*Eptesicus fuscus*; EPFU) echolocation calls recorded with an Anabat II detector at Chuck Swan Wildlife Management Area, Tennessee, May-August 2002 and 2003.

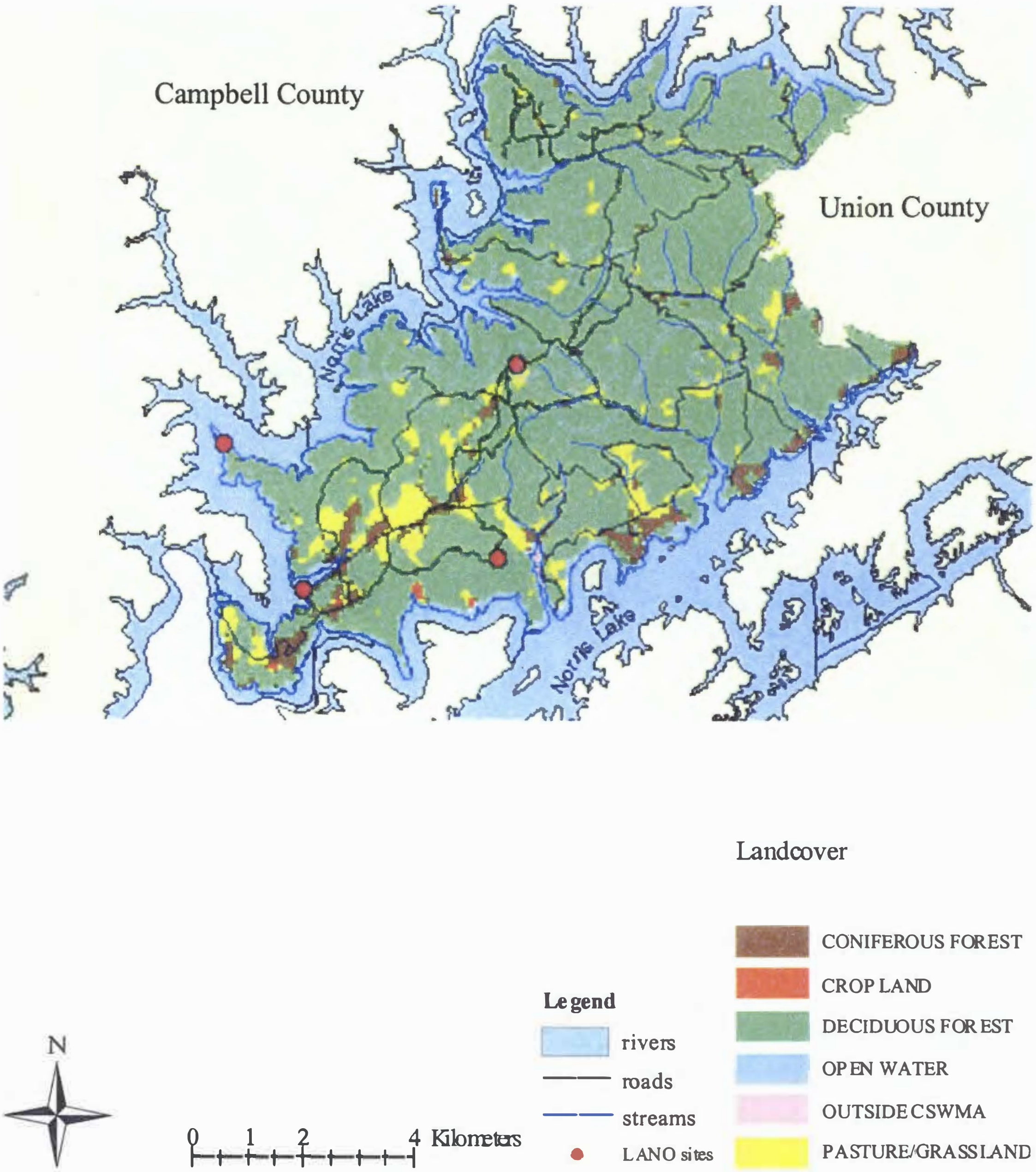


Figure 10. Location of silver-haired bat (*Lasionycteris noctivagans*; LANO) echolocation calls recorded with an Anabat II detector at Chuck Swan Wildlife Management Area, Tennessee, May-August 2002 and 2003.

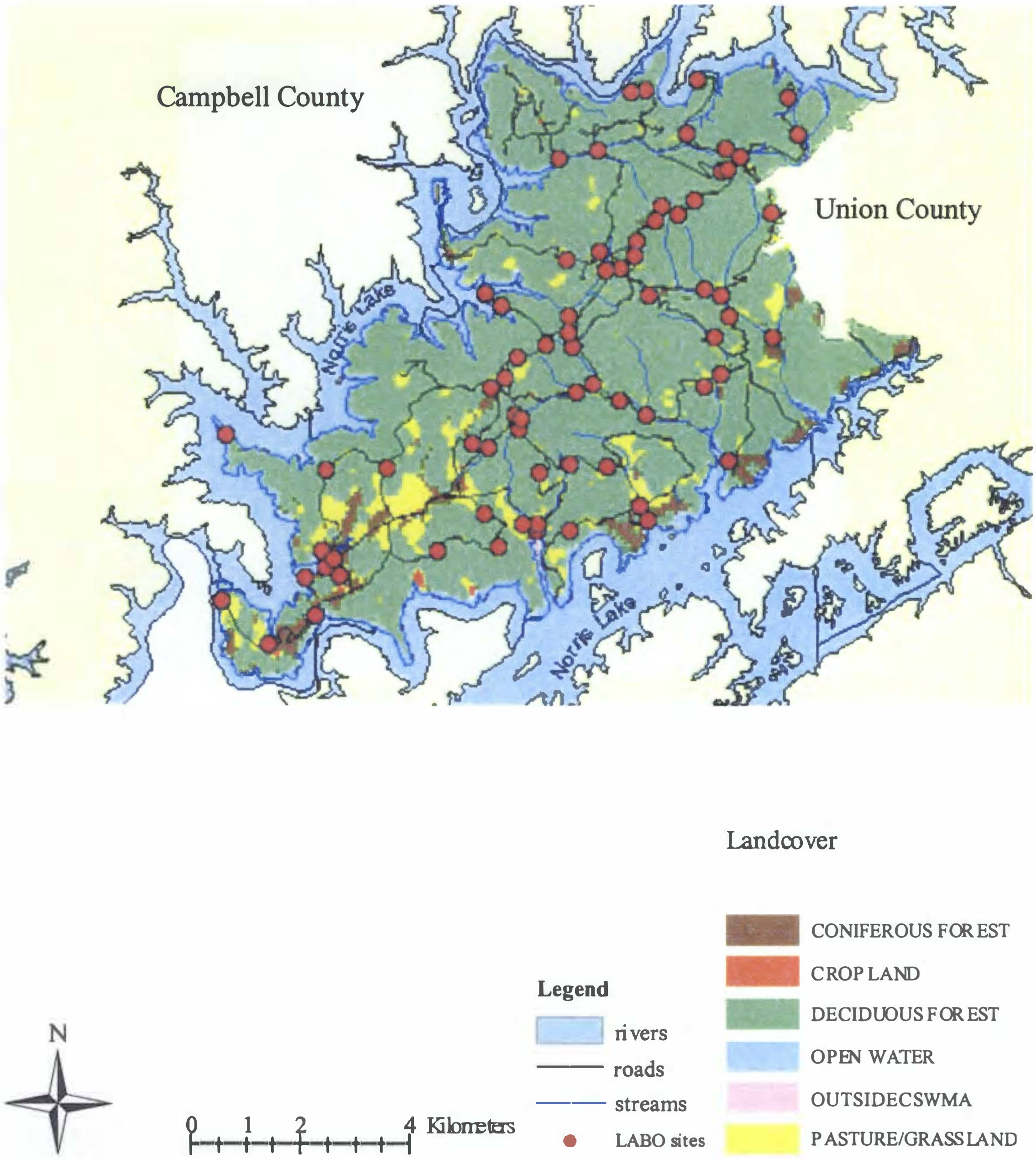


Figure 11. Location of eastern red bat (*Lasiurus borealis*; LABO) echolocation calls recorded with an Anabat II detector at Chuck Swan Wildlife Management Area, Tennessee, May-August 2002 and 2003.

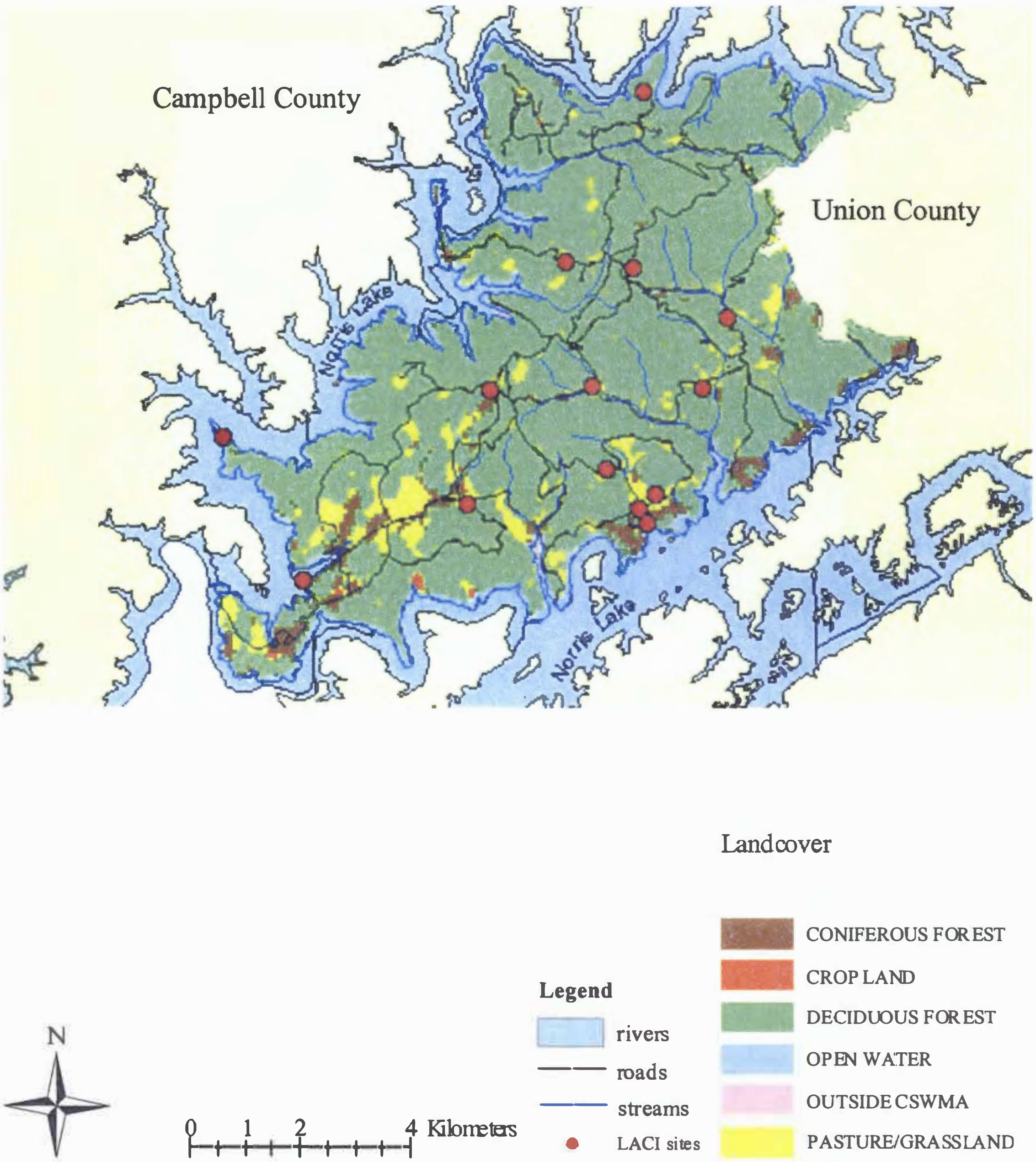


Figure 12. Location of hoary bat (*Lasiurus cinereus*; LACI) echolocation calls recorded with an Anabat II detector at Chuck Swan Wildlife Management Area, Tennessee, May-August 2002 and 2003.

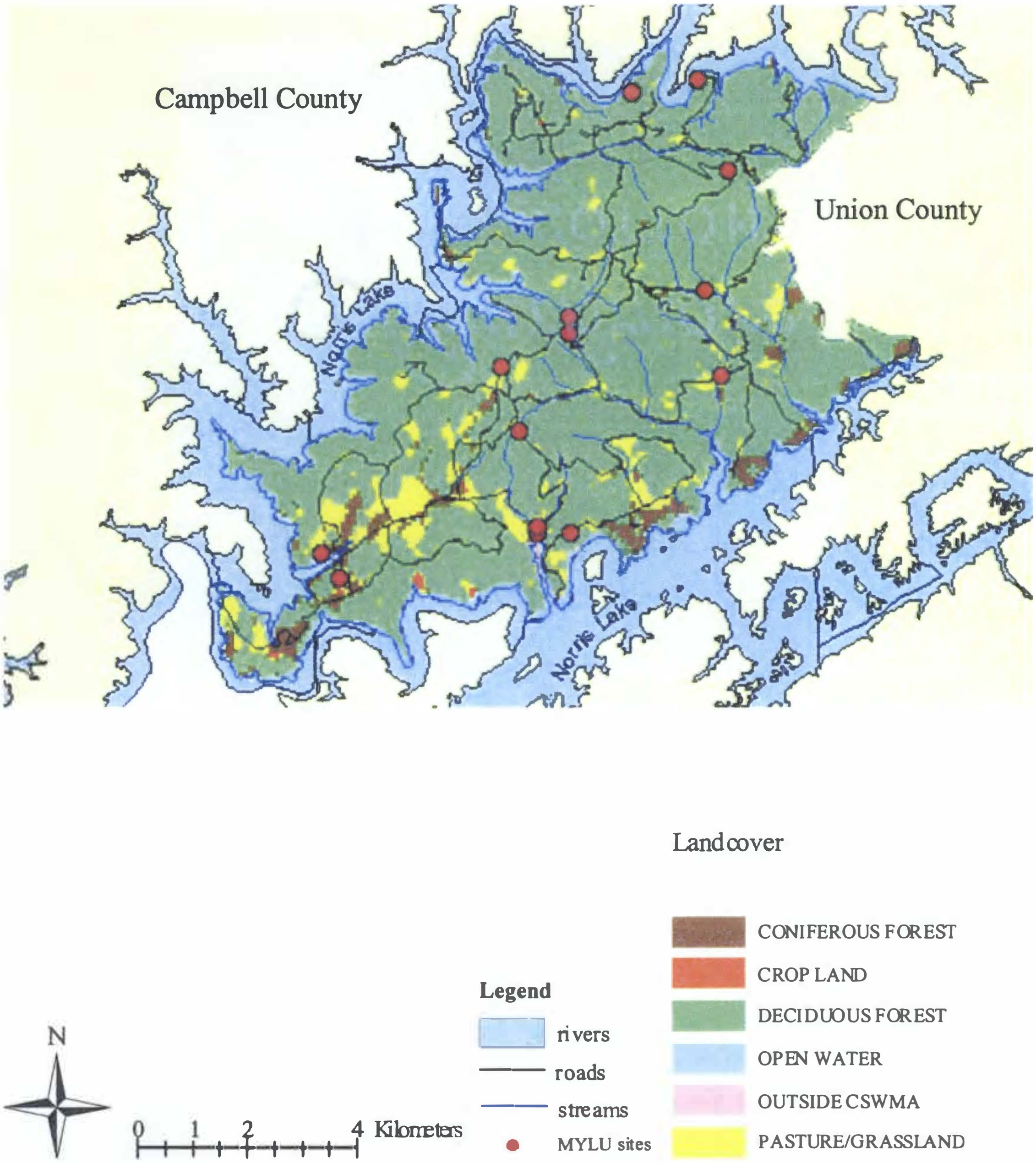


Figure 13. Location of little brown bat (*Myotis lucifugus*; MYLU) echolocation calls recorded with an Anabat II detector at Chuck Swan Wildlife Management Area, Tennessee, May-August 2002 and 2003.

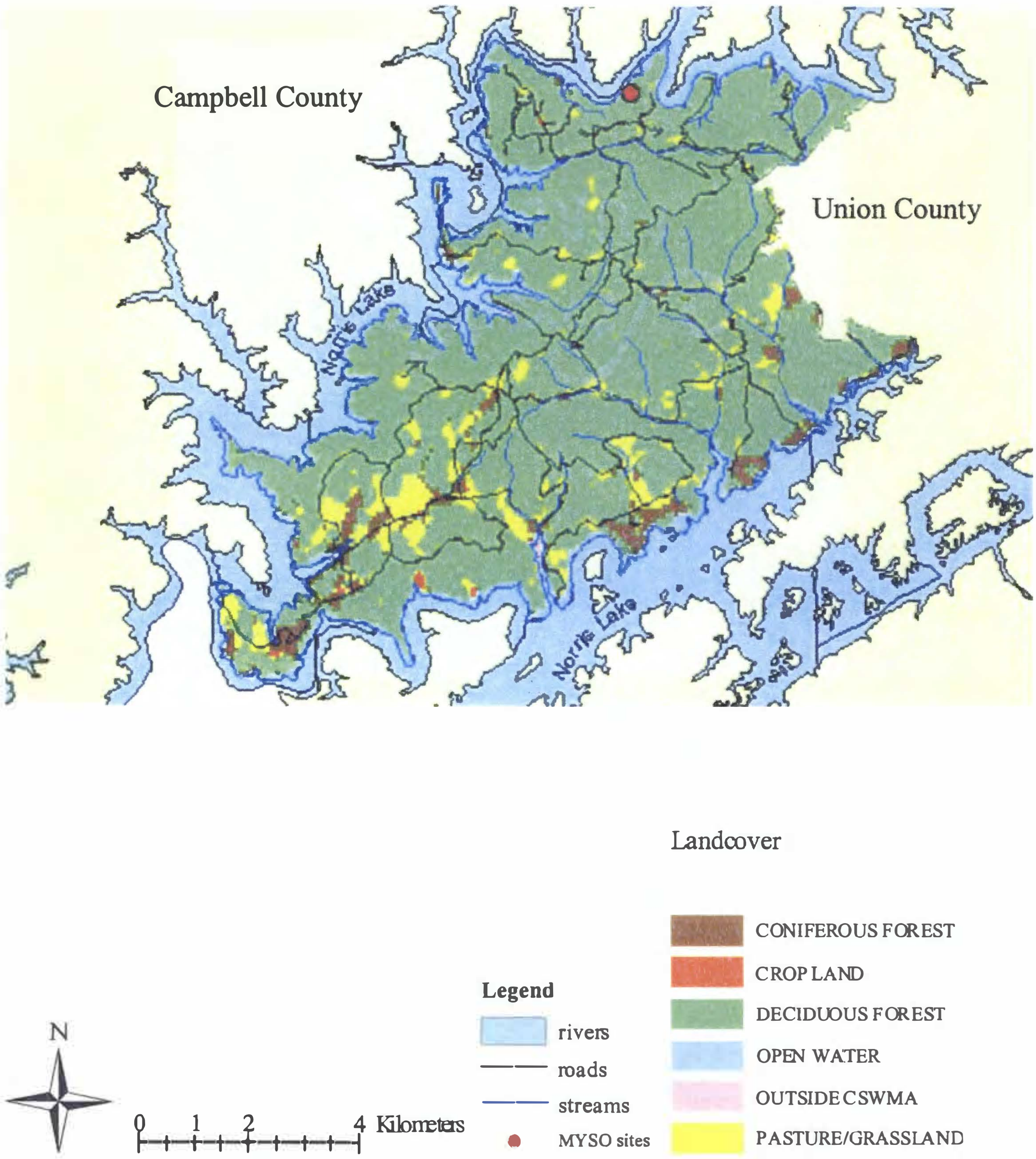


Figure 14. Location of Indiana bat (*Myotis sodalis*; MYSO) echolocation calls recorded with an Anabat II detector at Chuck Swan Wildlife Management Area Tennessee, May-August 2002 and 2003.

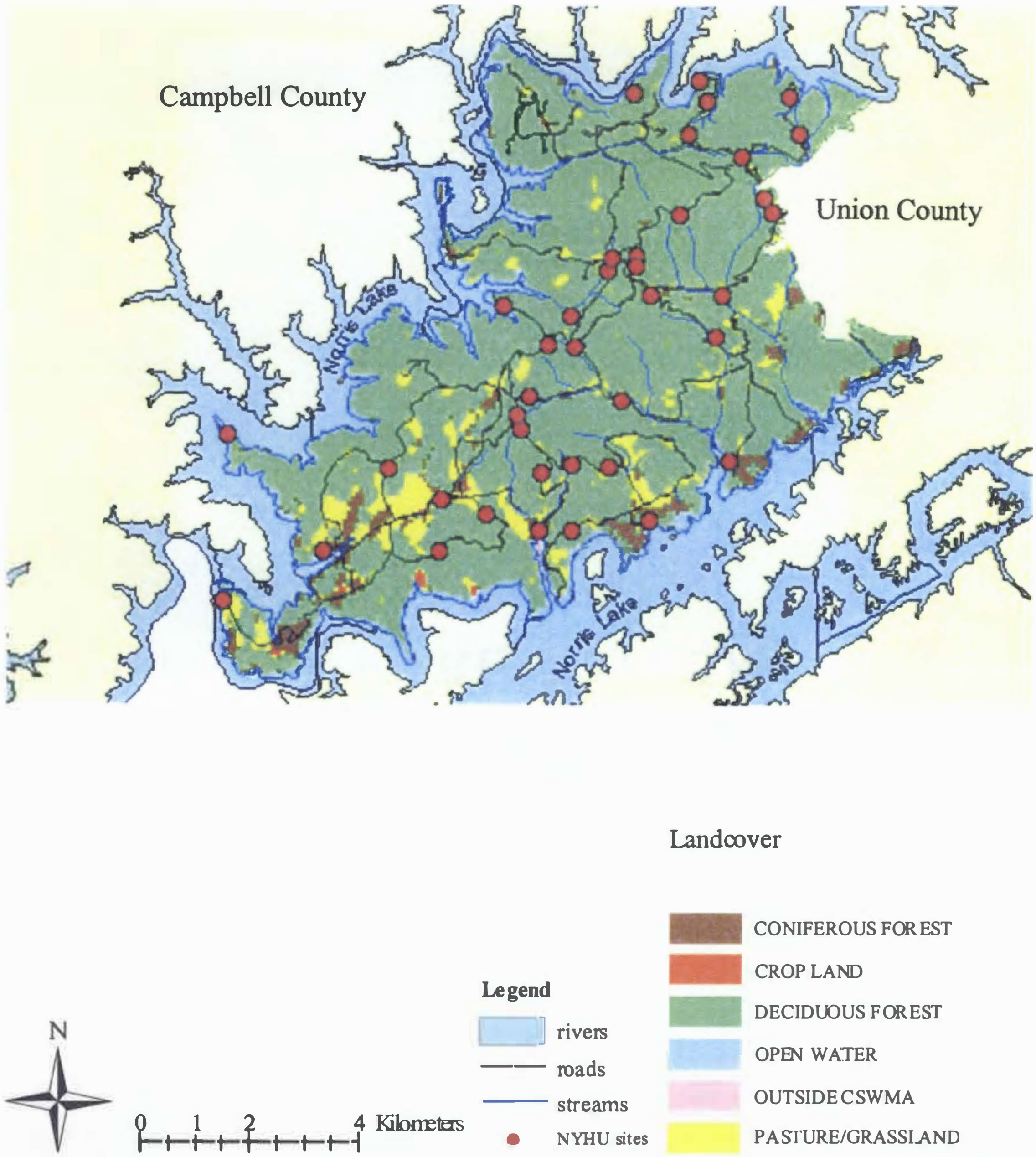


Figure 15. Location of evening bat (*Nycticeius humeralis*; NYHU) echolocation calls recorded with an Anabat II detector at Chuck Swan Wildlife Management Area, Tennessee, May-August 2002 and 2003.

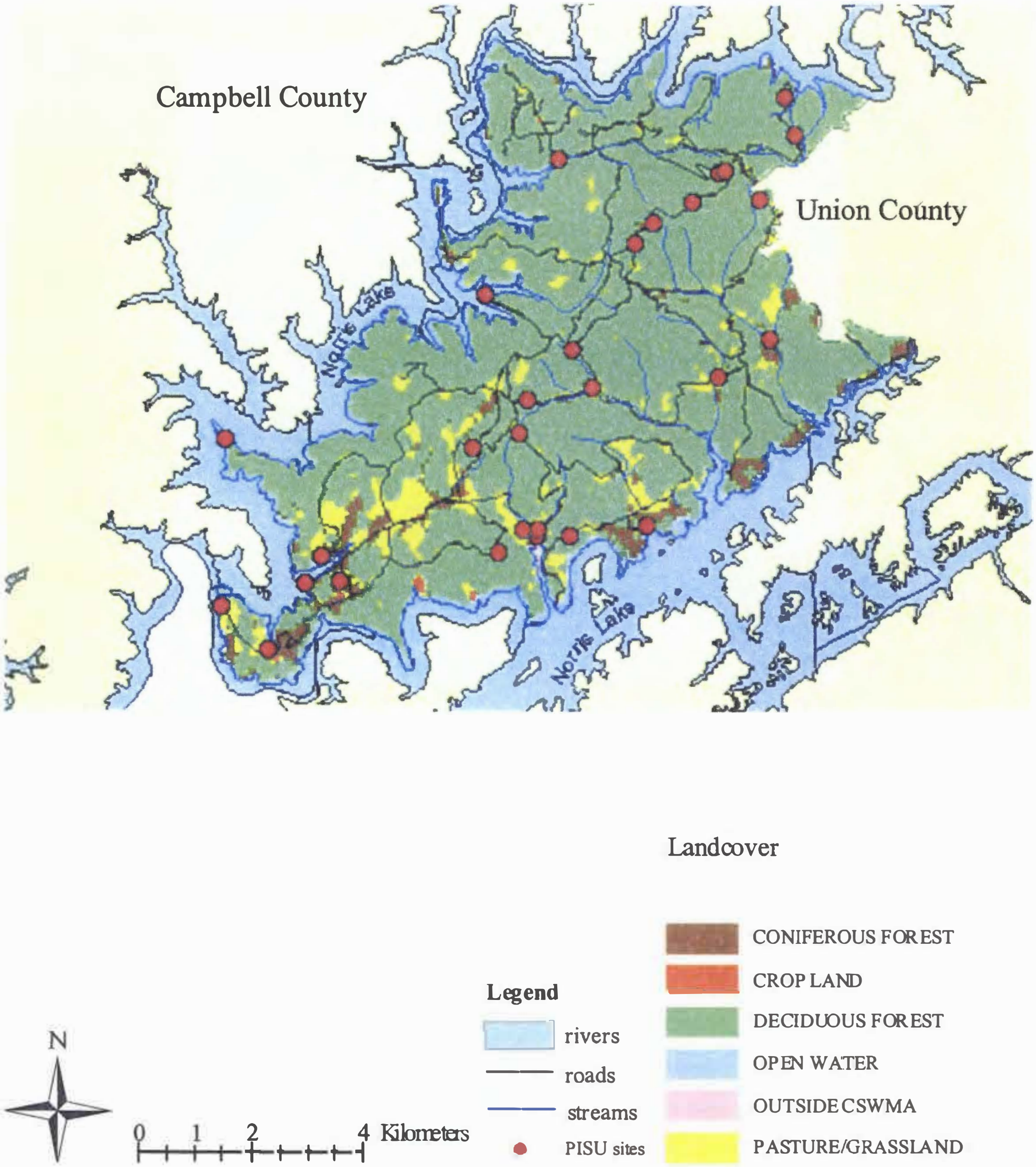
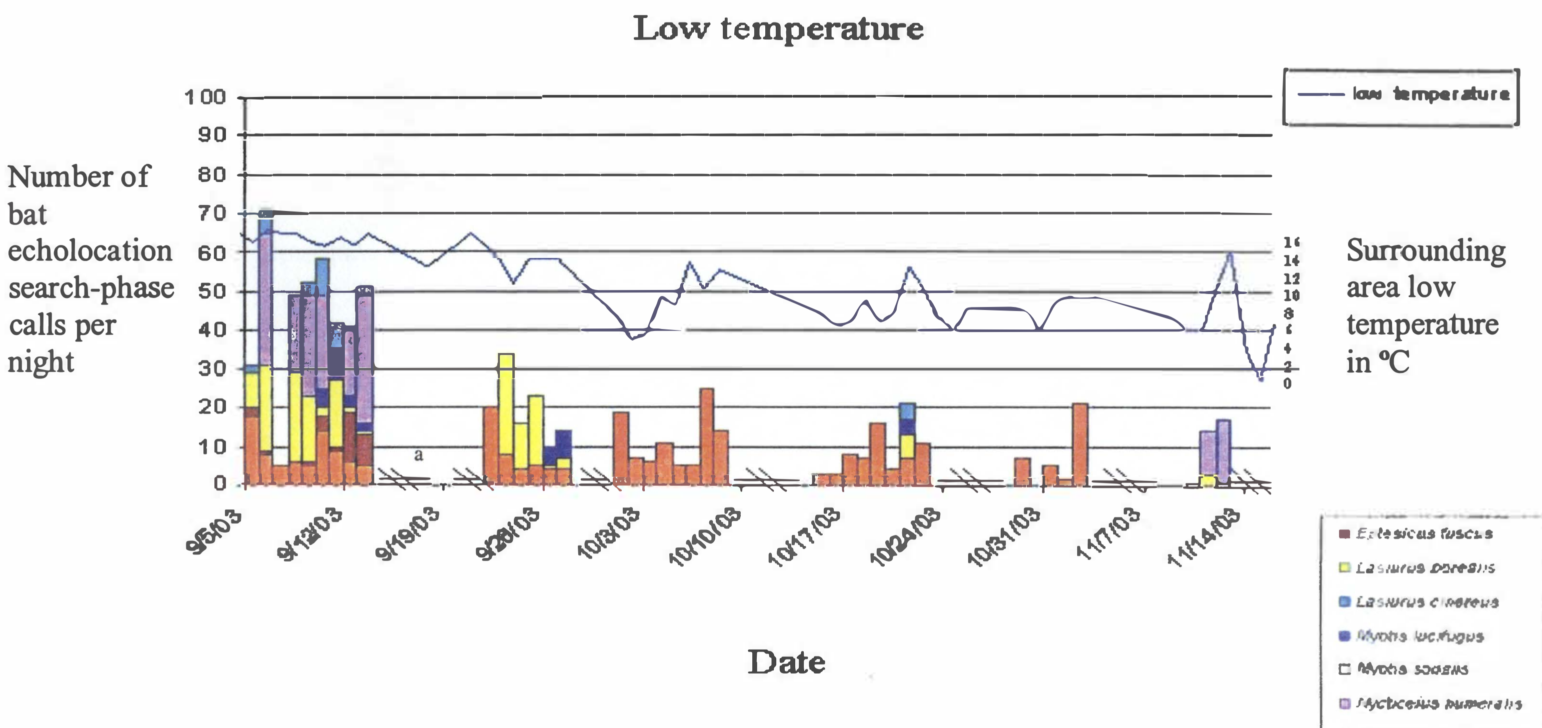
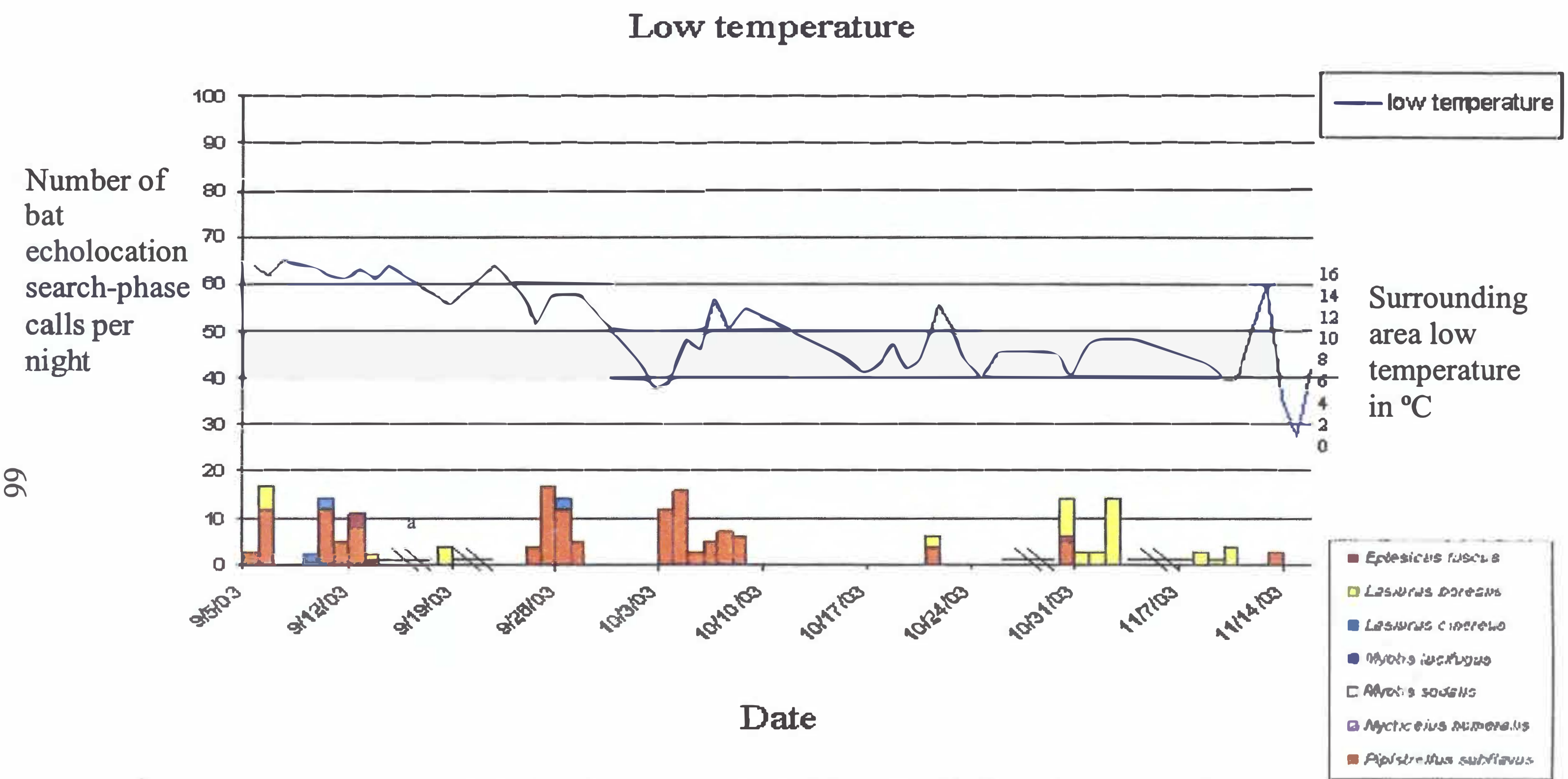


Figure 16. Location of eastern pipistrelle (*Pipistrellus subflavus*; PISU) echolocation calls recorded with an Anabat II detector at Chuck Swan Wildlife Management Area, Tennessee, May-August 2002 and 2003.



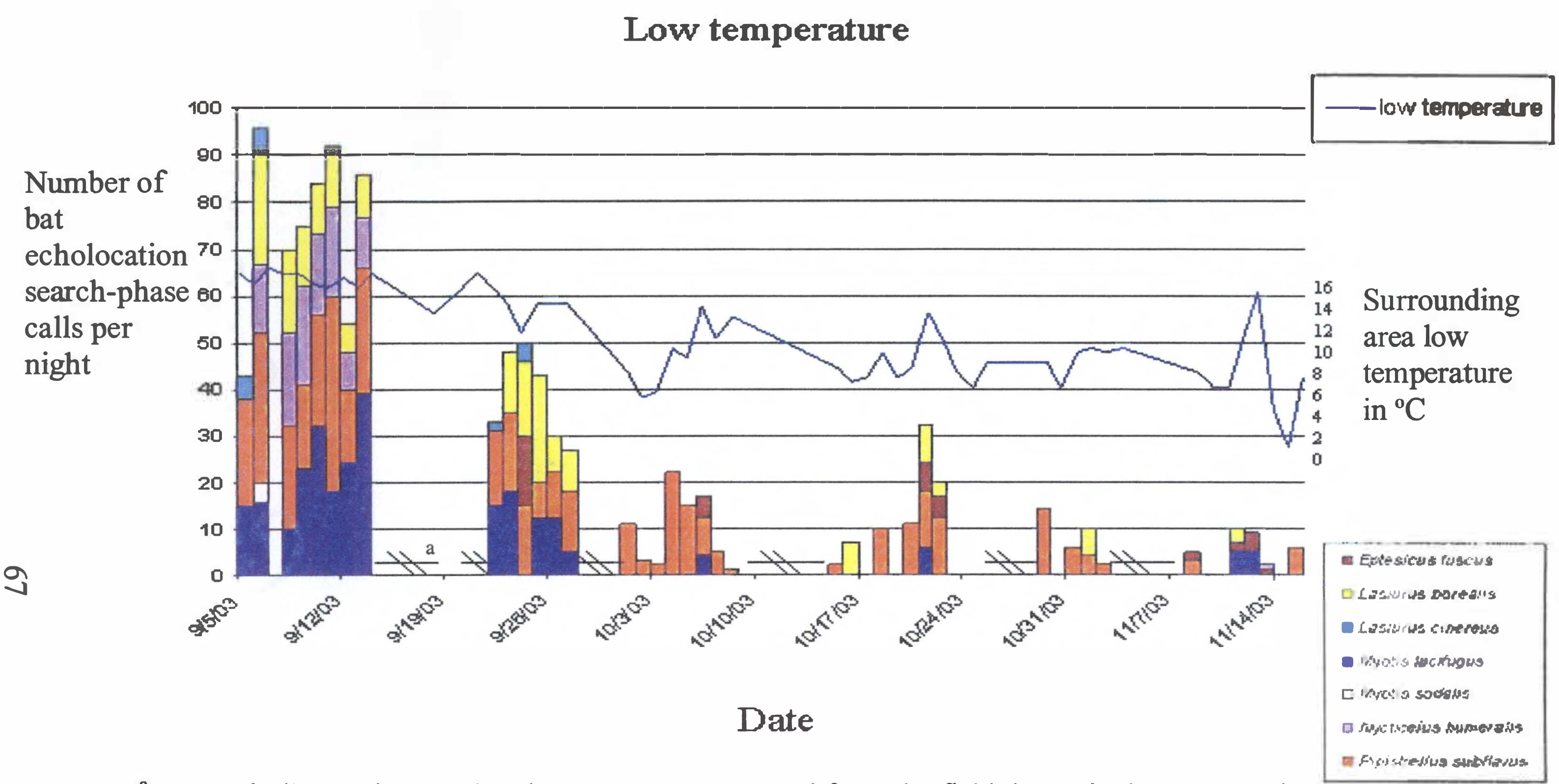
[a] indicates days anabat detectors were removed from the field due to inclement weather

Figure 17. Bat species found using an Anabat II bat detector at Oaks cave on Chuck Swan Wildlife Management Area, Tennessee, 5 September-15 November 2003.



a indicates days anabat detectors were removed from the field due to inclement weather

Figure 18. Bat species recorded using an Anabat II bat detector at Mossy Springs cave on Chuck Swan Wildlife Management Area, Tennessee, 5 September-15 November 2003.



[a] indicates days anabat detectors were removed from the field due to inclement weather

Figure 19. Bat species found using an Anabat II bat detector at Panther cave on Chuck Swan Wildlife Management Area, Tennessee, 5 September-15 November 2003.

VITA

Meaghan Shipley Wear, the daughter of H. Glenn and Elaine P. Shipley, was born in Chattanooga, Tennessee on June16, 1980. She graduated from Ooltewah High School in May 1998. She received her Bachelor of Science degree in Wildlife and Fisheries Science, with a minor in Forestry, from the University of Tennessee, Knoxville in December 2001. Meaghan then began her graduate research in Wildlife and Fisheries Science at The University of Tennessee, Knoxville in January 2002. She was awarded the Master of Science degree in Wildlife and Fisheries Science in December 2004. Her professional interests include wetland ecology, non-game ecology, and wildlife/habitat restoration.